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ABSTRACT

This course of study is aligned with the California State Science Framework and provides students the chemistry content needed to become scientifically literate and prepared for post-secondary science education. The course of study is divided into four sections. The first section provides an overview of the course and includes a course description, representative objectives, a time line, and the sequence of instructional units. The second section presents the course's 15 instructional units and enumerates the required concepts and skills to be taught. Topics covered by the units are: (1) skills and concepts required by the course; (2) atomic structure; (3) the concept of mole; (4) electrons and periodicity; (5) chemical bonding; (6) gases; (7) liquids and phase change; (8) solids; (9) solutions; (10) chemical kinetics; (11) equilibrium; (12) solubility equilibrium; (13) electrochemistry; (14) thermochemistry and thermodynamics; and (15) nuclear chemistry. The third section on lesson planning discusses various teaching strategies that foster scientific ways of thinking and encourage student creativity and curiosity. Seventeen sample lesson plans identifying specific objectives, instructional activities, practice formats, individual learner differences, and evaluation methods are provided. The fourth section contains two appendices: a list of 28 resources and a list of the standards for Physical Science from the "Model Curriculum Standards, Grades Nine through Twelve." (MDH)

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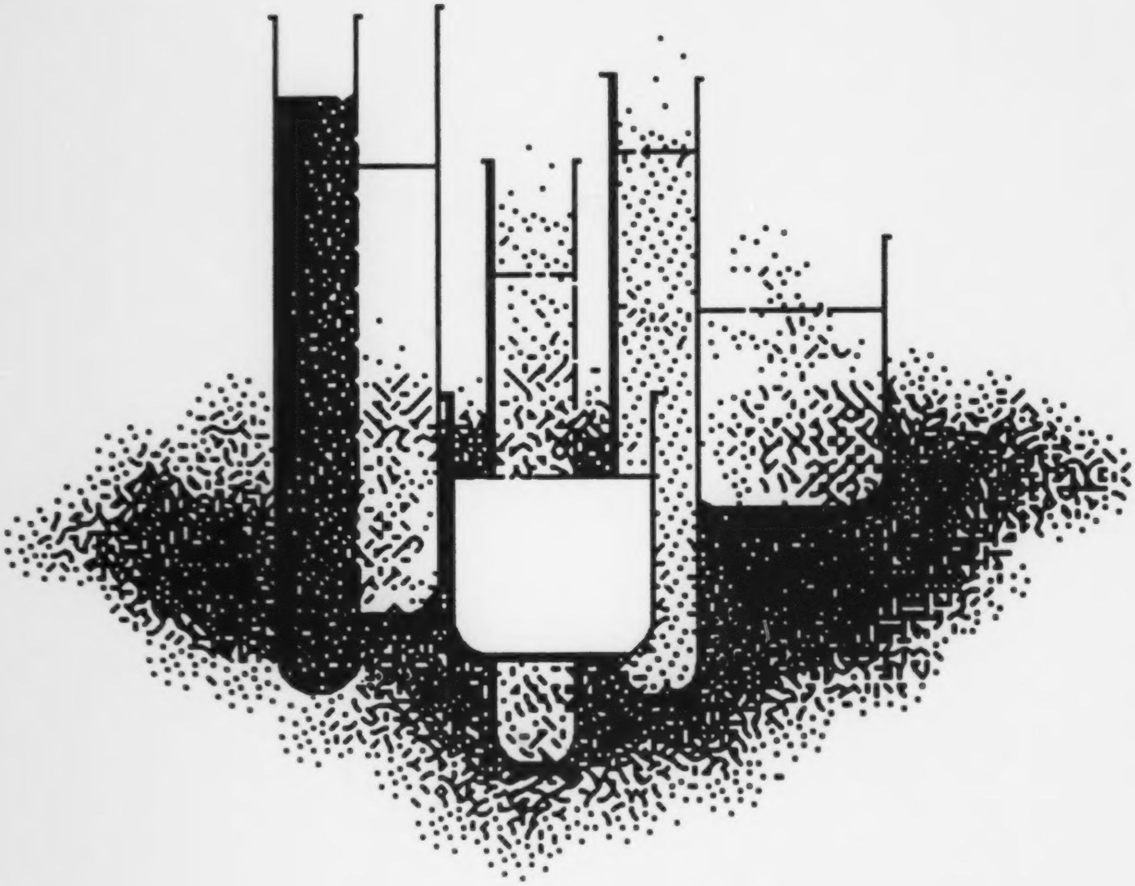
CHEMISTRY AB

COURSE OF STUDY



LOS ANGELES
UNIFIED SCHOOL DISTRICT
Office of Secondary Instruction
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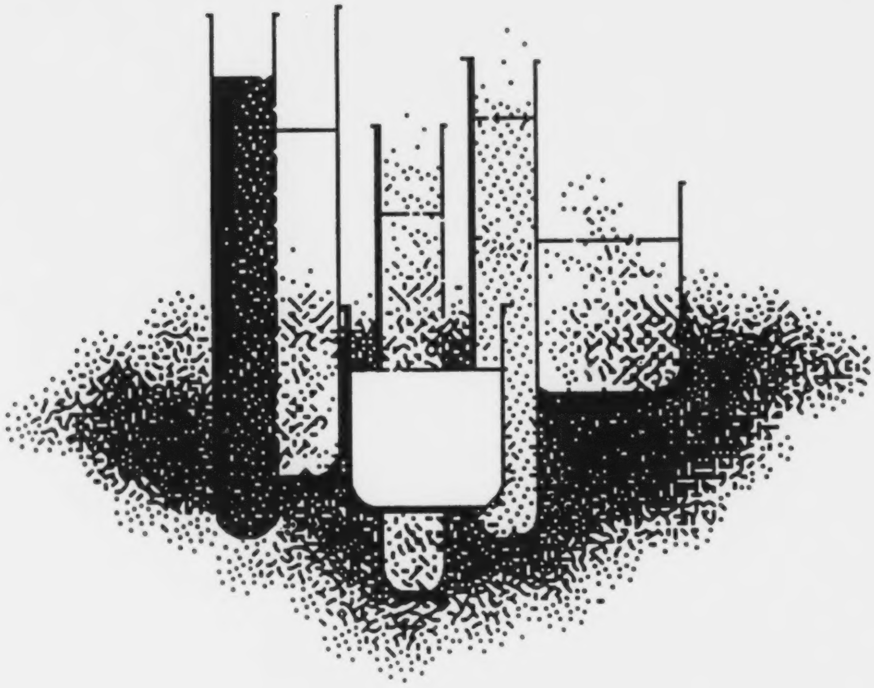

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FOREWORD

Scientists acquire and organize knowledge in order to explain natural phenomena and to make it of use to humankind. Through the science instructional program in secondary schools, students develop an understanding that science is a body of knowledge which changes as our understanding increases. Science is comprised of interconnected sets of principles, laws, and theories that explain the known universe and our relationship to it. Students investigate phenomena systematically and acquire and refine information. Outcomes include a greater understanding of how human beings use scientific information essential for comprehending our environment and for reaching solutions to problems of daily living.

Chemistry AB, an advanced academic elective senior high school course, is intended to assist students in preparing for other advanced academic science classes and higher education. It is designed to help students develop a basic knowledge of science as well as appropriate skills, learning processes, and attitudes. These outcomes are emphasized because they are fundamental to good citizenship and effective participation in today's society.

The Chemistry AB curriculum includes a study of matter, energy, and their interactions, with particular emphasis on an investigative approach to develop scientific understandings and attitudes. This course of study provides teachers with a time schedule and a sequence of units, required skills and concepts, samples of teacher-directed lesson plans and instructional strategies, and appendices of additional resources.

ACKNOWLEDGMENTS

Gratitude is expressed to those individuals who contributed to the development of this course of study by reviewing the content and recommending unit titles and concepts.

The Office of Secondary Instruction is especially grateful to RICHARD ERDMAN, Teacher, Venice High School; BLAINE FIFE, Science Department Chairperson, Van Nuys High School; DAVID KUKLA, Teacher, North Hollywood High School; and BARBARA SITZMAN, Teacher, Chatsworth High School, who developed the content and wrote the course of study.

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SECTION I:

OVERVIEW

COURSE DESCRIPTION AND REPRESENTATIVE OBJECTIVES

CHEMISTRY AB (Annual Course--Grades 11-12. Prerequisites: Algebra 1AB and Biology AB or equivalent. Emphasis: Physical Science)

36-14-01 Chem A
36-14-02 Chem B

Course Description

The major emphasis of this course is to develop the concepts of chemistry and to provide problem solving, laboratory investigation, and independent measurement techniques. Introduces skills and concepts required in Chemistry AB, atomic structure, the mole concept, electron configurations and periodicity, chemical bonding, the properties of gases, liquids and phase change, the properties of solids and solutions, chemical kinetics, equilibrium and solubility equilibrium, electrochemistry, thermochemistry and thermodynamics, and nuclear chemistry. Meets the grade 9-12 District physical science requirement. Meets University of California entrance requirement for one year of laboratory science.

According to his or her present capacities, the student grows in the ability to:

- Identify as important to the science of chemistry such activities as observing, describing, classifying, and testing.
- Demonstrate, in laboratory work, manipulative skills that result in measurements within acceptable limits of accuracy.
- Classify matter on the basis of physical and chemical properties.
- Explain the mole concept.
- Construct a theoretical model of the atom.
- Explain energy effects in chemical reactions.
- Demonstrate proficiency in chemical calculations and manipulative skills.
- Assemble and use laboratory apparatus, tools, and materials skillfully, with attention to safety precautions.

Application of Basic Skills

Provides an opportunity for students to demonstrate basic skills in areas of speaking and listening, writing, reading, and computation. Examples of these skills are:

Speaking and Listening

- Gather information from the instructor and from audiovisual media by watching and listening.
- Participate in group discussions.
- Gather information from the community for classroom presentations and discussions.

Writing

- Examine and evaluate major concepts.
- Write a scientific paper using the scientific method.
- Draw inferences from the content.
- Apply data from reading to practical problems.
- Make and substantiate hypotheses and generalizations.

Reading

- Identify main ideas.
- Become familiar with technical vocabulary.
- Read symbols, abbreviations, and formulas.
- Understand and interpret graphs and tables.
- Follow directions in laboratory work.
- Organize ideas from reading.
- Utilize sources to locate materials.

Computation

- Calculate solutions to problems using the basic operations of mathematical skills.
- Use a calculator when appropriate.
- Use the cognitive process necessary to solve problems.

Performance Skills

The student will:

- Assemble and use laboratory apparatus, tools, and materials in a skillful manner, giving due attention to safety measures.
- Gather needed information which has been generated by others from a variety of sources appropriate to his or her ability level.
- Record observations accurately and organize data and ideas in ways that improve their usefulness.
- Communicate with others in a manner that is consistent with knowledge.
- Use the metric system effectively.
- Apply appropriate mathematical concepts and skills in interpreting data and in solving problems.

TIME LINE AND SEQUENCE OF UNITS

UNIT	TOPICS	NUMBER OF WEEKS ALLOCATED
ONE	Introduction to Skills and Concepts Required and and Developed in Chemistry AB	Taught 2 weeks and also integrated throughout the course
TWO	Atomic Structure	2
THREE	Mole Concept	4
FOUR	Electrons and Periodicity	2
FIVE	Chemical Bonding	4
SIX	Gases	2
SEVEN	Liquids and Phase Change	2
EIGHT	Solids	2
NINE	Solutions	2
TEN	Chemical Kinetics	2
ELEVEN	Equilibrium	3
TWELVE	Solubility Equilibrium	3
THIRTEEN	Electrochemistry	3
FOURTEEN	Thermochemistry and Thermodynamics	2
FIFTEEN	Nuclear Chemistry	1
	Total	36

HOW TO USE THE COURSE OF STUDY

Section I of the course of study provides teachers with a summary of representative objectives and a time line and sequence of units. Teachers should read Section I first for an overview of the entire Chemistry AB course.

Section II provides teachers with the content for the fifteen instructional units. In addition, these units are prefaced with an introductory unit called "Skills and Concepts Required and Developed in Chemistry AB." After introducing this unit, teachers should integrate the skills and concepts throughout the course.

Each instructional unit contains an introductory page listing representative objectives. The remainder of each unit is formatted as two facing pages, each containing two columns. On the left-hand page, the first column contains a content outline for the regular Chemistry AB course. The second column contains suggested additional content for honors classes or enrichment. On the right-hand page, the third column indicates corresponding skills to demonstrate correlations with sources such as the State Model Curriculum Standards, Science. The fourth column contains references to student experiments, teacher demonstrations, and activities are provided as models for the implementation of the units. Teachers are encouraged to write-in additional activities and instructional resources in column four to provide a ready reference for local school development of teaching strategies.

Section III, correlated to the content columns in Section II, contains information and strategies necessary for effective lesson planning and sample lesson plans. The sample lesson plans and instructional strategies follow the teacher-directed lesson format. Appropriate worksheets follow each sample lesson.

Section IV contains the Appendices. These include teacher resources and a summary of the physical science section of the State Model Curriculum Standards, Science.

SUMMARY OF REPRESENTATIVE OBJECTIVES

Unit Title	Objectives
UNIT ONE - INTRODUCTION TO SKILLS AND CONCEPTS REQUIRED AND DEVELOPED IN CHEMISTRY AB	During the instructional program in Chemistry, students will: - Develop skills in handling equipment and materials common to the chemistry laboratory. - Use and precisely read the scales of measuring devices needed in chemistry activities. - Make observations and record data precisely. - Develop written and oral communication skills in reporting data and conclusions. - Interpret data using math skills generally used in chemistry. - Demonstrate the ability to express numbers in standard scientific notation and rewrite the quantity conventionally; perform mathematical computations using numbers in scientific notation; record both measured and derived values to the correct number of significant digits; compare laboratory data to accepted values; and use dimensional analysis (unit cancellation, unit conversion, factor label method) in chemistry problem solving.
UNIT TWO - ATOMIC STRUCTURE	- Distinguish between a compound and element when presented with the formula of a substance. - Distinguish between a compound and element when presented with a three dimensional molecular model.

Unit Title	Objectives
	- Identify four physical properties that will help identify a pure substance.
	- Compare positive and negatively charged ions and determine how atoms become ions.
	- Use a chart of common ions to write formulas and name ionic substances.
	- Assemble a model of a crystal structure using styrofoam balls of two different sizes.
UNIT THREE - MOLE CONCEPT	- Compare the relative masses of atoms.
	- Define a mole from three points of view.
	- Determine the molar mass of elements, compounds and ionic substances.
	- Balance a chemical equation by adding coefficients to the equation.
	- Solve stoichimetry problems.
	- Recognize that fuels give off specific amounts of heat in exothermic reactions.
	- Use the mole concept to express the concentration of a solution.
UNIT FOUR - ELECTRONS AND PERIODICITY	- Understand that scientific modeling is an important scientific tool.
	- Describe the hydrogen atom as quantized.
	- Describe an atomic orbital.
	- Categorize elements into groups.

Unit Title	Objectives
	- Identify physical and chemical properties of some groups of elements. - Determine the periodic trends in some properties such as ionization energies of elements.
UNIT FIVE - CHEMICAL BONDING	- Differentiate between ionic and covalent bonded substances by using the periodic table. - Draw Lewis dot (electron dot) structures for simple molecules. - Determine the shape of some simple molecules. - Distinguish between polar and nonpolar molecules. - Name at least four simple hydrocarbon compounds. - Arrange organic chemicals into functional groups when given the structural formulas of the substances.
UNIT SIX - GASES	- Understand the model of gas particles moving very rapidly in largely empty space. - Explain the behavior of gases using the Kinetic Molecular Theory. - Determine the effect of a change in temperature, volume, pressure, and/or number of molecules on the value of another variable using the gas law relationships. - Calculate the partial pressure exerted by each gas in a mixture of gases.

Unit Title	Objectives
UNIT SEVEN - LIQUIDS AND PHASE CHANGE	- Explain the forces of bonding which determine the properties of liquids.
	- Calculate the energy involved in phase changes.
	- Recognize liquids as materials with strong intermolecular forces and intermediate kinetic energies
	- Use the Kinetic Molecular Theory to explain evaporation and vapor pressure.
	- Recognize that pure substances have characteristic melting and boiling points.
UNIT EIGHT - SOLIDS	- Relate the characteristic properties of solids to their strong interparticle attractions and low kinetic energies.
	- Describe the arrangement of ions and molecules crystals.
	- Describe the process of sublimation.
	- Identify the four types of solids by their physical characteristics
UNIT NINE - SOLUTIONS	- Express the concentration of a solution in terms of molarity.
	- Describe the effect of temperature on the dissolving process.
	- Recognize the role of energy in the dissolving process.
	- Use the solubility rules to predict the formation of a precipitate during the mixing of two or more solutions.

Unit Title	Objectives
	- Relate solubility to the polarity of molecules.
	- Explain the effect of the addition of a solute on the freezing and boiling points of a solution.
UNIT TEN - CHEMICAL KINETICS	- Measure and compare rates of reaction.
	- Compare the rates of catalyzed and non-catalyzed reactions
	- Compare the change in rate of reaction which occurs as the ratio of surface area to mass is changed.
	- Compare the change in rate of reaction which occurs as a result of temperature change.
UNIT ELEVEN - EQUILIBRIUM	- Gain knowledge that equilibrium is an essential aspect of chemistry.
	- Gain in understanding of the interrelationships of temperature, pressure, and the equilibrium state of chemical reactions.
	- Compare various ways of defining acids and bases and the relative advantages of each.
	- Understand the relationship between titration and the change in pH.
	- Refer to a table of indicators to determine which is appropriate for the measurement of a given pH.

Unit Title	Objectives
UNIT TWELVE - SOLUBILITY EQUILIBRIUM	- Understand the meaning of the terms "soluble" and "insoluble." - Demonstrate ability to predict when precipitation will occur. - Explain how precipitates may be dissolved. - Appreciate the importance of buffered systems in chemical reactions and natural processes.
UNIT THIRTEEN - ELECTROCHEMISTRY	- Understand how electrochemical reactions may be used to produce electricity. - Balance reduction-oxidation equations. - Relate use of electricity to to the decomposition of molecules into elements.
UNIT FOURTEEN - THERMOCHEMISTRY AND THERMODYNAMICS	- Understand the importance of chemical synthesis and the accompanying energy changes. - Relate the relationships between energy transfers and the conditions necessary for chemical reactions to occur. - Understand that the gain or loss of heat is extremely important in the change of phase of matter. - Relate heat to its gain or loss and the conversion of heat into work. - Relate the Kinetic Molecular Theory model to matter around them. - Understand units of measurement and specific heat.

Unit Title	Objectives
UNIT FIFTEEN - NUCLEAR CHEMISTRY	- Gain in understanding of the relationships of heat, energy, chemical reactions, and work. - Appreciate the basis of how spontaneous changes can occur. - Understand the basic concepts of nuclear science. - Describe how radioactivity can be used to improve understanding of objects around us. - Distinguish between harmful and beneficial uses of nuclear energy. - Compare methods of detecting radioactivity.

SECTION II:

INSTRUCTIONAL UNITS

Weeks Allocated - 2
(The concepts and skills in this unit are also integrated throughout the course.)

UNIT ONE: INTRODUCTION TO SKILLS AND CONCEPTS REQUIRED AND DEVELOPED IN CHEMISTRY AB

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Use fundamental skills in the handling of materials and equipment common to chemistry.
- Gather, organize, and communicate scientific information.
- Use basic math skills common to chemistry.
- Develop rational and creative thinking processes.
- Gain fundamental knowledge as it pertains to the processes, theories, principles, and concepts of chemistry.
- Develop values and responsible attitudes which promote their understanding of the impact of chemistry on society.

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
UNIT I. INTRODUCTION	
I. Development of Fundamental Skills	
A. Materials and equipment commonly used in the chemistry laboratory include solid and liquid reagents, balances, bunsen burners, and basic glassware.	
B. Mass, volume, and temperature are measured in accepted SI units. A quantity has two parts: the amount (number) and the measurement label (unit).	
C. The number of significant figures is determined by the precision of the measuring instrument. Measurements include the digits which are certain plus one estimated digit. The uncertain digit is the limitation inherent in the ability to read the instrument.	Record the amount of uncertainty with each measured value.
Precision is the reproducibility of measurement, the quantity of measurement uncertainty; accuracy refers to how closely a value compares to an accepted value; and exact numbers, such as conversion factors, have no measurement uncertainty.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
Students will develop skills in handling equipment and materials common to the chemistry laboratory.	
Students will learn to use and precisely read the scales of measuring devices needed in chemistry activities.	See Sample Lesson 1 for volume by direct measurements and water displacement (Honors: Archimedes Principle); dimensional analysis and measurement uncertainties; and density.
Students will make observations and precisely record data.	Observation lab activities record data may include burning candle or matches, and aluminum foil/$CuCl_2$ solution reaction.
Students will develop written and oral communication skills in reporting data and conclusions.	

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
D. Numbers of very large or very small magnitude are expressed in exponential (scientific) notation. Rules are followed to determine the correct number of significant digits for all mathematically derived values.	Error and precision are treated quantitatively. Calculate and record the amount of uncertainty for each value derived from laboratory data. Recognize the most precise of two values.
E. Chemistry is a sequential course which involves the gradual building of concepts. Notebooks containing class notes, text work, and laboratory reports will be maintained in a clear, organized manner throughout the course	
F. Chemistry problems involving concepts such as density, gas laws, and concentration can be solved using dimensional analysis.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
Students will interpret data using math skills generally used in chemistry. Students will demonstrate the ability to: express numbers in standard scientific notation and rewrite the quantity conventionally; perform mathematical computations using numbers in scientific notation; record both measured and derived values to the correct number of significant digits; compare laboratory data to accepted values; and use dimensional analysis unit cancellation, unit conversion, (factor label method) in chemistry problem solving.	Practice dimensional analysis with nonsense problems. Wards Solo Learn filmstrips: "Scientific Notation" and Significant Figures"

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
II. Development of Rational and Creative Thinking Processes	
A. All District secondary science courses should include laboratory activities. It is reasonable to assume that chemistry students will spend more time in the laboratory than most other science students.	
B. Chemistry is an experimental science. Laboratory experiences provide the empirical basis for understanding and confirming concepts. Through laboratory work students develop a basic understanding of the scientific approach to problem solving. A laboratory experiment begins with a testable question.	
C. Observations may be qualitative or quantitative. They must be distinguished from interpretations. Encourage honesty in reporting data.	Numbered, duplicate page laboratory notebooks encourage the honest recording of empirical data by reducing the temptation to dry lab.
D. Laboratory data is usually organized in data table form. Quantities may be graphed or represented mathematically.	
E. Relationships are determined by studying patterns in empirical data. Graphs can show direct or inverse relationships. They may allow extension of data beyond measured quantities (extrapolation).	Use mathematical relationships to solve quantitative problems. State regularities both in words and in mathematical formulas at an advanced level.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
F. Inquiry involves the generation and use of data to form theories which provide rational explanations of observed phenomena.	
G. Comparison of individual data to class data and/or accepted values provides the basis for the development and understanding of chemical concepts as well as the recognition of valid data and error analysis.	
H. Interpretation of data suggests new testable questions and provides the basis for further experiments.	Information obtained from laboratory activities will be applied to new situations. A testable question forms the basis for experimental design activities in which students form hypotheses and experimentally test their predictions.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
It is recommended that the chemistry student spend approximately one and one-half hours per week involved in hands-on activities.	
Students will write complete, concise reports of work demonstrating the ability to:	
1. Recognize a problem, predict, and develop possible solutions.	
2. Observe, describe, and record data collected experimentally.	
3. Organize data in an orderly, meaningful manner and express patterns in graphical form.	
4. Interpret charts, tables, and graphs.	
5. Compare their own data to class data and/or accepted values.	
6. Use empirical and theoretical mathematical relationships to solve quantitative problems.	
7. Interpret relationships in nonmathematical language.	Mystery Powders Lab
8. Recognize data which supports a scientific theory.	
9. Draw conclusions from data.	
Students will show an understanding of the role of inquiry in solving problems relating to chemistry. They will use this process to develop explanations (theories) which are consistent with empirical data.	See Sample Lesson 2, Introduction to Experimental Design Problems, especially for honors students. Inquiry problems are encouraged and include items such as: dunking duck, pulse glass, and Cartesian diver.
Students will relate data acquired during laboratory investigations to scientific concepts and models.	
Students will use the processes of science as problem solving tools outside the classroom.	

III. Development of Scientific Process Skills

A. A short class discussion of laboratory techniques and safety precautions will precede most laboratory activities. Title, purpose, procedure, and tables for data constitute the pre-lab portion of a report. Students must complete these sections before each laboratory exercise. Chemistry pre-labs are usually homework assignments.

B. A formal laboratory report is written on quadrille (graph) paper. Experimental observations are recorded neatly, objectively, and honestly.

C. After students have processed their own data a comparison of class data is used to tie experimental analysis to the understanding of chemical principles. Interpretation of data usually follows a post-lab discussion. The purpose and interpretation sections of a laboratory report are written in paragraph form using complete sentences.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
Laboratory Report Format	
*Experiment Number and Title	
-*Purpose: statement(s) answering some or all of the questions: What new skills or techniques are you using? What chemical principles are you investigating? What results do you predict?	
- Materials: list of materials or simple sketch of apparatus used	
-*Procedure: brief sentences giving step by step procedure (Student lab manuals do not belong at lab stations.)	
-*Observations and Data: data organized in neatly boxed tables including all observations, qualitative and quantitative (Include amount and measurements recorded to the precision of each instrument used.)	Record uncertainties with all measured data.
-*Analysis of Data: calculations set up with proper units and dimensional analysis to solve problems (Graphs and histograms of class data belong in this section.)	
- Error Analysis: discussion of sources of error and their effects on experimental results; comparison of results to accepted values	*This required section will include calculation of uncertainty on derived values (both percentage and amount of uncertainty); detailed discussion of measurement limitations and environmental effects on data; magnitude and direction of these effects; and acknowledgment of the range of uncertainty in accepted values.
- Analytical Interpretation: (or conclusion) evaluation of the data; a short summary of the patterns and explanations found in the data; and new, testable questions which can lead to further investigation	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
In the chemistry laboratory students will: - Demonstrate the ability to write formal reports using the information given in standard laboratory manuals or in experimental design assignments. - Learn laboratory techniques and develop skills in using basic chemistry laboratory equipment. - Refer to the original purpose of the investigation in their interpretation of the data. - Relate abstract concepts learned in classroom chemistry to actual experiences and real life situations such as the development of new products and the seeking of solutions to environmental pollution problems. - Develop experimental design strategies including the ability to formulate a testable questions and design an experiment to collect appropriate data to investigate the problem.	

- Technological Application: evaluation and application of the relationships found in data to general chemical principles; the application of critical thinking skills to real life (everyday) situations including current scientific issues and career choices.

*These sections are required; others are optional and should be included when appropriate.

IV. Development of Values and Responsible Attitudes

  A. Safety is a primary concern in the chemistry laboratory.

    1. Safety instruction involves both teacher and student responsibilities.

      a. The teacher's responsibility is to instruct all students in the safe use of basic equipment and reagents. Written safety instructions will be given to each student enrolled in chemistry. Specific precautions for each laboratory situation are given in pre-lab discussions and reinforced during the activity period.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT

Students will demonstrate knowledge and respect for safety procedures during laboratory exercises. Goggles and aprons will be worn whenever chemicals or heat are used.

Students will appreciate the value of using those processes involved in scientific and inquiry approaches to problem solving.

Students will show awareness of the limitations of science.

Students will recognize the value of recording data honestly.

Students will demonstrate an interest in extending their laboratory work beyond the requirements of the course.

Students will become aware of the connections between chemistry and other fields of study.

LABORATORY/DEMONSTRATIONS

Safety test
Bergwald filmstrip/cassette:
"Working in the Laboratory"

**STUDENT SAFETY CONTRACT

I, _______________ have read and agree to abide by the safety regulations as set forth above and also the additional printed instructions provided by the teacher. I further agree to follow all other written and verbal instructions given in class.

("Safety in the Secondary Science Classroom," National Science Teachers Association)

Date _______________

____
Student Signature

I have read and discussed the "Safety Instructions for Chemistry Students" and the "Student Safety Contract" with my son/daughter.

____
Parent Signature

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
b. Students will assume responsibility for learning, understanding, and practicing safe conduct in the laboratory at all times. An intentional and serious breach of safety rules must be dealt with appropriately and immediately.	
2. Students must know the location and proper use of safety equipment including goggles and aprons.	
3. Each student must pass a written safety test before participating in laboratory activities. The reading and signing of a safety contract by both students and parents may be required.	
B. The steps of the scientific process are learned while students work as scientists in the laboratory situation.	
C. The understanding of the tentative nature of science is an important part of the scientific process.	
D. Most laboratory activities require cooperation between members of student pairs.	
E. A positive attitude toward the development of personal, social, and environmental skills will be encouraged.	The interdisciplinary nature of science will be emphasized.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
Students will realize the possible impact of chemistry on their daily lives.	Classroom discussions of current issues involving chemistry and the environment.
Students will demonstrate a positive attitude with respect to self and others.	
	See Sample Lesson 3, An Open-Ended Discussion on Environmental Issues.

UNIT II: ATOMIC STRUCTURE

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Distinguish between a compound and element when presented with the formula of a substance.
- Distinguish between a compound and element when presented with a three dimensional molecular model.
- Identify four physical properties that will help identify a pure substance.
- Compare positively and negatively charged ions and determine how atoms become ions.
- Use a chart of common ions to write formulas and name ionic substances.
- Assemble a model of a crystal structure using styrofoam balls of two different sizes.

UNIT II. ATOMIC STRUCTURE

I. Matter is made up of small particles.

   A. Matter can be categorized as elements, compounds, or mixtures.

      1. An element is a pure substance made up of only one kind of atom.
      2. A compound is a pure substance made up of more than one kind of atom.
      3. A mixture is a combination of different kinds of matter.

   B. The physical properties of elements and compounds give clues to their identity and behavior.

      1. The appearance of a substance sometimes leads to its identity.
      2. The melting and boiling points of substances reveal much about their identity and structure.

II. Chemical symbols and formulas are used as chemical shorthand.

   A. The symbols of the elements are always either one or two letters.

   B. Chemical formulas describe the number of atoms in a substance.

The periodic table shows how families of elements are related by common properties.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 1: Students demonstrate an understanding of atomic structure by sketching a typical atom and labelling its parts.	
MCS 1: Students will observe the properties of compounds by preparing and separating several different compounds (e.g., sugar and water, hydrogen, and oxygen, etc.).	Demonstration: Show students the difference between elements and compounds with molecular model kits or styrofoam balls of the same or different sizes.
MCS 3: Students will construct a phase-change investigation (e.g., water or paraffin) and then construct a phase change chart and supply the correct process for the phase-to-phase change. Vocabulary words to be included are solidifying, freezing, melting, evaporation, condensation, and sublimation.	Demonstration: Show students examples of as many elements as possible. Demonstration: Pure substances, such as p-dichlorobenzene, have definite melting points which are determined by melting them slowly in a test tube with a thermometer.
MCS 4: Students will explain the similar properties exhibited by a family of elements, for example by preparing a report on the chemical properties of a chemical family.	

CONTENT: CHEMISTRY — HONORS/ENRICHMENT

1. Nonmetallic elements combine to form substances with molecular formulas.
    - a) The atoms of some elements combine to form molecules.
        - If the atoms that combine are the same kind of atom, the result is an element.
        - If the atoms that combine are not the same kind of atoms, the result is a compound.
    - b) Molecules can be thought of as independent units of some elements or compounds.
    - c) Subscripts depict the number of atoms of each element in the molecular formula.
    - d) The names of simple molecules can be determined from a few rules.
2. Ionic substances are composed of charged particles called ions.
    - a) Atoms are made up of protons, neutrons and electrons.
    - b) When atoms lose electrons, they become positively charged.
    - c) When atoms gain electrons, they become negatively charged.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
	Demonstration: Dissolve some ionic substances in water. Activity: Students dissolve $CuSO$ and $FeCl_3$, add NH_3 to Cu^{2+}, and OH to Fe^{3+} solution.

C. Ionic substances

1. Ionic substances are composed of positive and negative ions and are neutral.
2. Formulas of ionic substances can be correctly written using knowledge of positive and negative ions.
3. Some ions are made up of atoms that act as a unit, such as, $SO4^{2-}$.
4. The positive ion is usually mentioned first in the name of an ionic substance.
5. Ionic crystals are a regular arrangement of + and - ions. These crystals are held together with a force of attraction that is great in comparison to many other kinds of chemical forces.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 3: Students will investigate crystal formation and describe the observable results of viewing drops of solutions of salt, sugar, and copper sulfate by means of a microprojector or low power microscope.	
Recognizes that atoms are composed of electrons, protons, neutrons, and other particles.	
Recognizes that electrons are negatively charged and protons are positively charged.	
Illustrates that the number of atomic particles varies with each element.	Students will investigate molecular and ionic substances. They will view examples of each under a microscope. They will observe and record the similarities and differences in appearance, melting points, and conductivity.
Students will be able to use a chart of common ions to write formulas and name ionic substances.	
Students should understand that NaCl means Na_nCl_n.	

UNIT III: THE MOLE CONCEPT

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Use the mole concept to express the concentration of a solution.
- Compare the relative masses of atoms.
- Define a mole from three points of view.
- Determine the molar mass of elements, compounds, and ionic substances.
- Balance a chemical equation by adding coefficients to the equation.
- Solve stoichimetry problems.
- Recognize that fuels give off specific amounts of heat in exothermic reactions.

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
UNIT III: THE MOLE CONCEPT	
I. The relative masses of atoms is a key concept in understanding chemistry.	
A. Atoms of different elements have different masses because of the number of particles they contain.	The atomic mass of an element can be calculated from the masses and relative abundances of the isotopes of this element.
B. The relative masses of some atoms are H = 1, Al = 27 and U = 238.	
C. Relative masses of atoms can be measured in the lab as grams, therefore H = 1g, Al = 27g and U = 238g. Each sample contains the same number of atoms.	
II. Avogadro's number is 6.022×10^{23}	
A. A mole of anything is Avogadro's number of that thing.	Molar mass means the same as molecular weight, molecular mass, formula weight, gram atomic weight, and gram atom.
B. Molar mass is the mass in grams of one mole of particles.	
III. Chemistry deals with molar quantities.	
A. Some mole problems convert grams to moles.	
B. Other mole problems convert moles to grams.	
C. Moles can be used to determine the empirical formula of a compound.	
D. Percent composition by mass is calculated using moles.	The mass percents of the elements in a compound can be calculated from its chemical formula.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 6: Students will describe the rearrangement that occurs in a simple chemical reaction by means of assembling and reconstructing molecular models.	Students will find the relative mass of three gases: oxygen, carbon dioxide, and natural gas. Relative weights can be established in this lab.
MCS 6: Students will describe a variety of chemical reactions, including decomposition and replacement, by observing and then writing the equation for the decomposition of water and the replacement when iron replaces copper in a solution of copper II sulfate.	See Sample Lesson 4. The students will determine the mass of a hydrate. Then upon heating, they will determine the mass of the anhydrous salt. From masses and from calculations with moles, they will be able to determine the formula of the hydrate. Barium chloride or magnesium sulfate work very well.
MCS 6: Students will investigate chemical reactions that result in release of energy by carrying out an investigation in which zinc and hydrochloric acid are combined and the temperature change measured. Students shall also explain the temperature change or light produced when various commercial products are used (e.g., cold or heat packs used for injuries, light rods used for camping).	

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
IV. Stoichiometry deals with mole relationships in balanced chemical equations.	
A. Chemical equations clearly define reactants and products.	
B. Formulas of substances must be written correctly in chemical equations.	
C. Mass is conserved in a chemical reaction.	The laws of Conservation of Mass, Constant Composition, and Multiple Proportions relate to the atomic theory.
D. Atoms are conserved in chemical reaction.	
E. Chemical equations can be balanced by adding coefficients to the formulas to show conservation of atoms.	
F. It is often time-saving to balance hydrogen and oxygen atoms last.	
V. Problems involving reaction stoichiometry involve three kinds:	The limiting reagent determines the maximum amount of product that can be formed in a reaction.
A. Mole-mole	
B. Gram-Mole	
C. Gram-gram	
VI. Energy is conserved in a chemical reaction.	
A. Energy is absorbed or given off when compounds or elements are reformed into other compounds or elements.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 10: Students will determine the various exchanges and conversions of different forms of energy by tracing gasoline back to its source and then discussing its use in an automobile. Recognizes the uses of fuels.	
MCS 6: Students will compare and contrast examples of chemical equilibrium (e.g. slightly soluble products with physical equilibrium (e.g., the pressure of sealed versus opened bottles of soda pop).	
	See Sample Lesson 5. The students will determine the molarity of a dilute HCl solution. They will react a known volume of dilute HCl solution with a measured mass of calcium carbonate. This lab reinforces the need for using balanced equations. Alternate: Make molarity known and let the students find the volume of HCl needed to react. Demonstration: the procedure for making a 1.0 M NaCl solution.

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
B. Endothermic refers to a reaction that absorbs energy from the surroundings.	
C. Exothermic refers to reaction that gives energy off to the surroundings.	
VII. Molarity is the ratio of moles of solute to liters of solution.	
A. Molarity refers to the degree of concentration of a solution.	
B. Problems dealing with molarity are often divided into three kinds: 1. unknown molarity 2. unknown grams 3. unknown volume	Molarity is often used to determine the amount of product in a chemical reaction.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

UNIT FOUR: ELECTRONS AND PERIODICITY

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Understand that scientific modeling is an important scientific tool.
- Describe the hydrogen atom as quantized.
- Describe an atomic orbital.
- Categorize elements into groups.
- Identify physical and chemical properties of some groups of elements.
- Determine the periodic trends in some properties such as ionization energies of elements.

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
UNIT IV. ELECTRONS AND PERIODICITY	
I. The modern history of the atom began near the turn of the 20th century.	
A. The atom was discovered to consist of smaller particles called electrons, protons, and neutrons.	
B. E. Rutherford is credited with the discovery of the nucleus.	Describe the atomic model deduced from Rutherford's experiment.
II. The bright-line spectrum of the hydrogen atom was first explained by N. Bohr.	
A. The electromagnetic spectrum consists of a series of waves of differing frequencies.	
B. Atoms and molecules absorb photons at only specific frequencies and no others.	
III. Thy hydrogen atom can exist at only certain energy levels.	
A. The hydrogen atom (and other atoms) is said to be quantized.	
B. The bright-line spectrum of hydrogen can be interpreted by way of the quantized atom.	
C. N. Bohr described the hydrogen atom as a nucleus with an orbiting electron.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 4: Students understand that elements are arranged in a periodic table. In addition, they learn that properties of elements are related to the number and "arrangement" of the electrons, protons, and neutrons that compose their atoms.	
Identifies examples of kinetic and potential energy.	
Identifies pairs of objects having similar properties.	
Given some properties for elements in a column, students should be able to predict the corresponding properties for a missing element in the same family.	Activity: Use a power supply to show students the bright line spectra of several elements. Students need diffraction grating.
A student should be able to identify the family of an element if given a description of its physical and chemical properties.	Demonstration: The visible light spectrum is shown by using a slide projector, narrow slit, and prism or transmission diffraction grating.
	Demonstration: Show various bright line spectra with diffraction grating and a power source.
	Lab: The students will measure the yellow lines in the bright line spectrum of sodium. They will set up two meter sticks and a diffraction grating so that they can measure the angle of diffraction of yellow light. Using Beer's law, they will determine the wavelength of light.

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
IV. The modern atomic theory is called the Wave Mechanical Model.	
A. This theory describes the electrons in the mathematics of waves.	A relationship exists between the wavelength of light absorbed by a species and its color.
B. An orbital is a region around the nucleus in which there is a high probability of finding an an electron.	Review and discuss the work of Bunsen and Kirchoff and the invention of spectroscopy.
C. Orbitals are given names, such as 2s, 2p which indicate the energy levels of the electrons.	
D. The electrons in ground state atoms can be described by electron configurations.	Review and discuss Heisenberg's Uncertainty Principle and Schrödinger's Wave Equation in relation to electron orbitals.
V. Some elements have similar chemical and physical properties. This phenomenon is called periodicity.	
A. The periodic table is arranged according to increasing atomic number.	
B. Elements with similar properties are placed below each other.	
C. Elements can be broken into three groups called metals, nonmetals, and metalloids.	
VI. Electron configurations can be used to predict groupings of elements.	
A. Groups 1 and 2 are characterized by either one or two electrons in the outermost s orbitals.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
Students demonstrate an understanding of the trends in ionization energy across rows and down columns of the periodic table.	
	Lab: The students will discover the periodic trend in the reactivity of the halogens from Cl to I. They will also discover the acid/base nature of some oxides indicating a gradual change in the nature of the oxides across the periodic table.
Superconductivity is an unpredicted yet important property of some compounds.	

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
B. Groups 17 and 18 are characterized by either 7 or 8 electrons in the outermost s and p orbitals.	Electron configurations and orbital diagrams can be drawn for the elements.
C. The electron configurations of the noble gases give these elements much stability.	Discuss the conditions under which the noble gases form compounds and the properties of these compounds.
D. The periodic table can be used to predict chemical activity.	Atomic radii decrease in size as one moves from left to right across the periodic table. Atomic radii increase in size as one moves down a group.
E. Ionization energy of atoms can be predicted from the periodic table.	Second, third, and fourth ionization energies can be used to interpret the stability of positive ions.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

UNIT V: CHEMICAL BONDING

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Differentiate between ionic and covalent bonded substances by using the periodic table.
- Draw Lewis dot (electron dot) structures for simple molecules.
- Determine the shape of some simple molecules.
- Distinguish between polar and nonpolar molecules.
- Name at least four simple hydrocarbon compounds.
- Arrange organic chemicals into functional groups when given the structural formulas of the substances.

UNIT V. CHEMICAL BONDING

I. Chemical bonding is produced by forces that allow a group of atoms to act as a unit.

   A. Ionic bonding occurs between positive and negative ions.

   B. Electron configurations may be used to predict the formulas of ionic substances.

   C. When crystal lattices grow, energy is released as heat.

   D. Ionic substances have relatively high melting points, are brittle, and do not conduct electricity as solids.

II. A covalent bond occurs between atoms of nonmetals.

   A. A covalent bond is the result of the sharing of a pair of electrons.

   B. A polar bond results when bonded atoms do not share electrons equally.

   C. Bonding in molecules can be represented by Lewis dots or electron dots.

   D. The bonding in many molecules may be predicted by using the octet rule.

   E. There are many exceptions to the octet rule.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
Students will relate the type of bonding between atoms to the location of elements on the periodic table.	See Sample Lesson 6 in which students will discover the structure of simple molecules. Using ball and stick models they will construct molecules. They will also use balloons to determine the shape of molecules.
A student will identify a compound as containing predominately ionic or covalent bonds based on its chemical and physical characteristics.	
Students will draw electron dot and structural formulas to represent bonding between atoms.	Lab: Calculate the energy of crystallization of sodium thiosulfate pentahydrate.
Students will use the principles of chemical bonding to predict the shape of molecules.	
MCS 7: Students will describe the rearrangement that occurs in a simple chemical reaction by means of assembling and reconstructing molecular models.	See Sample Lesson 7 in which the students will investigate some properties of crystals and relate them to the strength or the chemical bonds.

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
III. The geometry of molecules determines many of their chemical and physical properties.	
A. The geometry of molecules is three dimensional.	
B. The number of atoms bonded and the number of unshared pairs of electrons around the central atom determines the shape of the molecule.	Some molecules and complex ions exhibit the property of resonance. An explanation that combines electron configurations with the geometry of molecules is called hybridization.
C. The Valence Shell Electron Pair Repulsion Theory explains the geometry of many molecules.	
D. Molecules can have a number of shapes, including linear, bent, and tetrahedral.	Some molecules have more complex geometries, such as phosphorus pentachloride or sulfur hexafluoride.
E. Some molecules are nonpolar and the smaller ones have relatively low boiling points.	
IV. Organic chemistry is the study of the properties and bonding of carbon atoms.	
A. Carbon and hydrogen combine to form in almost an infinite variety of molecules.	
B. Hydrocarbons can be classified as either cyclic or noncyclic.	
C. A functional group is the important part of an organic molecule that determines the molecule's properties.	
D. Some of the compounds of silicon have properties similar to organic materials.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
Students will relate properties such as boiling points to the polarity of molecules.	Demonstrate: Show the difference between space filling models and stick and ball models.
Students will draw all the possible structural isomers of a given compound.	Lab: Using ball and stick models or marshmallows, toothpicks, and gumdrops students will build all the possible isomers of a six carbon, single bonded hydrocarbon.
MCS 7: Students understand the importance of the synthesis of new compounds which have properties needed to serve certain purposes.	
MCS 7: The students will appreciate the role of synthesis in medicine by preparing a report on synthetic materials used in the health field. (Include vitamins, plastics, heart valves, etc.)	
	Demonstrate: Emphasize the variety of organic substances by showing students examples of organic compounds and their formulas.
	Lab: The students will make esters from various alcohols and organic acids.

UNIT VI: GASES

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Understand the model of gas particles moving very rapidly in largely empty space.
- Explain the behavior of gases using the Kinetic Molecular Theory.
- Determine the effect of a change in temperature, volume, pressure, and/or number of molecules on the value of the other variable using the gas law relationship.
- Calculate the partial pressure exerted by each gas in a mixture of gases.
- Solve stoichiometric problems given volumes of gases as reactants and products.

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
UNIT VI: GASES	
A. Substances with high kinetic energies and much intermolecular space are called gases. The characteristics of a gas are dependent on pressure, volume, and temperature.	
B. There are definite relationships between pressure, temperature, and volume called Boyle's, Charles', Gay-Lussac's, and the Combined Gas Laws.	
C. The Ideal Gas Law relates the mass of a sample to P, V, and T. 1. Volume, absolute temperature, and number of moles are directly proportional in an ideal gaseous system. 2. Pressure is inversely related to the other three variables.	Physical properties of a gas sample may be used to find the molecular mass of the gas.
D. The total pressure of a gas sample containing many gases is the sum of the partial pressures of each gas.	
E. The relative speed at which molecules of two gases move is a function of their molecular masses and the temperature of the system.	
F. The properties of gases can be explained by the Kinetic Molecular Theory (Boltzman Distribution).	Real gases do not behave exactly according to the gas laws.
G. The amount of gas formed in a reaction is a stoichimetric function.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 3: Students understand the three basic phases of matter on earth and the role temperature and pressure play in the change of phase. Students will be able to relate the kinetic theory model to matter around them.	Soda can demonstrate gas pressure.
MCS 3C: Students will understand the relationship between pressure, volume, and temperature of gases.	Absolute pressure demonstration apparatus is available from the Science Materials Center.
MCS 5: Students learn to define, measure, and/or calculate various physical characteristics of substances (e.g., mass, weight, length, area, volume, and temperature).	Demonstration: Boyle's Law (either using water and gas collecting tube or sealed syringe and books). Molar Volume of a Gas Lab (Mg and HCl). See Sample Lesson No. 8, Determining the Molar Mass of Butane Lab.
	Demonstration: Graham's Law.
	Demonstration: Hoffman Apparatus.

CHEMISTRY AB Weeks Allocated 2

UNIT VII: LIQUIDS AND PHASE CHANGE

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Explain the forces of bonding which determine the properties of liquids.
- Calculate the energy involved in phase changes.
- Recognize liquids as materials with strong intermolecular forces and intermediate kinetic energies.
- Use the Kinetic Molecular Theory to explain evaporation and vapor pressure.
- Recognize that pure substances have characteristic melting and boiling points.

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
UNIT VII: LIQUIDS AND PHASE CHANGE	
A. Materials with relatively strong molecular attractions and intermediate kinetic energies exist as liquids at room temperature. Intermolecular bonding (e.g., hydrogen, dipole, and London disperson forces) determines the the properties of liquids such as surface tension, freezing and boiling points and vapor pressure.	The phases of matter can be represented graphically as a phase diagram.
B. Energy is involved in the changing of one phase of a substance to another.	
C. Evaporation occurs when high energy molecules break free of the sample and create vapor pressure in a closed system.	
D. Substances have a specific normal boiling and melting temperature that is a characteristic of that substance.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 3: Students understand the three basic phases of matter on earth and the role temperature and pressure play in the change of phase. Students will be able to relate the kinetic theory model to matter around them.	Demonstration: Surface Tension
All chemical reactions either absorb or release energy.	See Sample Lesson 9 in which the heat of fusion of ice is determined.
MCS 3: Students will construct a phase-change chart and supply the correct process for phase-to-phase change.	Demonstration: Vapor pressure
	Demonstration: Graham's Law
	Demonstration: Hoffman Apparatus

UNIT VIII: SOLIDS

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Relate the characteristic properties of solids to their strong interparticle attractions and low kinetic energies.
- Describe the arrangement of ions and molecules crystals.
- Describe the process of sublimation.
- Identify the four types of solids by their physical characteristics.

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
UNIT VIII: SOLIDS	
A. Solids are substances with strong interparticle attractions and low kinetic energies. Particles in a solid are arranged in a regular pattern called crystal lattices.	Solid substances can exist in three kinds of cubic lattice.
B. Under certain P and T conditions, a solid can produce a vapor without first becoming liquid. This process is called sublimation.	
C. There are four types of solids (ionic, metallic, covalent, and molecular) which vary in hardness, conductivity, and melting point depending on the bonding and type of particle occupying the lattice.	Some solids are conductors, some are semiconductors, and some are nonconductors due to the energy of their valence electrons.
D. Some crystalline solids trap water within their lattice structures.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 3: Students demonstrate their understanding of sublimation by describing the behaviors of dry ice, frost formation, and moth balls.	Demonstration: Models of NaCl Lattices
Properties of chemical compounds are related to the structure of their molecules or crystals. Properties of new compounds can often be predicted.	Demonstrations: Properties of dry ice
MCS 2: Students will investigate the common and chemical properties of metals and relate them to their uses in the environment.	See Sample Lesson 10 in which students investigate some properties of solids.
	Formula of a Hydrate Lab See Unit 3, Sample Lesson 4 if not done previously.

UNIT IX: SOLUTIONS

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Express the concentration of a solution in terms of molarity.
- Describe the effect of temperature on the dissolving process.
- Recognize the role of energy in the dissolving process.
- Use the solubility rules to predict the formation of a precipitate during the mixing of two or more solutions.
- Relate solubility to the polarity of molecules.
- Explain the effect of the addition of a solute on the freezing and boiling points of a solution.

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
UNIT IX: SOLUTIONS	
A. A solution is a uniform mixture of two or more substances that are physically combined. The relative amounts of the materials in a solution can be measured in several ways (e.g., mass % and molarity).	Molality is another way of expressing concentration that is important in determining the effect of solute on freezing and boiling points.
B. At a given temperature there is a maximum amount of a solute that can be dissolved in a given amount of water.	
C. Energy is always involved in the dissolving process.	
D. Solubility rules allow one to predict whether a precipitate will form when two solutions are mixed together.	
E. Whether a substance will or will not dissolve in another (its miscibility) depends on the polarity of the two substances.	
F. Changes in the proportion of solute to solvent cause corresponding changes in certain properties of a solution (e.g., freezing and boiling point, and vapor pressure).	The vapor pressure of solutions is a function of the relative moles of the solvent and solute. The osmotic pressure of a substance is dependent on the amount of solute added. Electrolytes have a greater effect on solution properties than nonelectrolytes.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
	See Sample Lesson 11, in which the solubility curve of a salt is determined.
	Demonstration: Saturated/ Supersaturated
Properties of chemical compounds are related to the structure of their molecules or crystals. Properties of new compounds can often be predicted.	Precipitation Lab Qualitative Analysis Lab
MCS 2: Students will appreciate the myriad of compounds that can be formed from different chemical combinations of elements.	Demonstration: Ammonia Fountain
When ionic crystals are dissolved in water, the ions can move about; and the solution becomes an electrical conductor.	
When chemical reactions occur, chemical bonds are broken. New chemicals form as atoms are rearranged in new combinations. The beginning substances are called reactants; the resulting substances are called products.	

UNIT X: CHEMICAL KINETICS

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Measure and compare rates of reaction.
- Compare the rates of catalyzed and non-catalyzed reactions.
- Compare the change in rate of reaction which occurs as the ratio of surface area to mass is changed.
- Compare the change in rate of reaction which occurs as a result of temperature change.

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
UNIT X: CHEMICAL KINETICS	
I. Chemical reactions proceed at different rates. Examples range from explosions which are very fast to the production of the green patina on copper roofs which takes many years.	
II. The rate of a chemical reaction may be expressed as the change in concentration of a chemical species per unit time (moles/liter/sec).	Derive the Rate Law.
A. Factors that Determine the Rate of a Chemical Reaction	
1. Nature of Reactants 2. Concentration of Reactants 3. Effect of Temperature	
a. Increasing the temperature increases the average kinetic energy of a system and the number of collisions.	An increase of ten degrees celcius approximately doubles the reaction rate.
b. Molecules with sufficient kinetic energy to form the activated complex are more likely to react.	
4. Effect of Catalysts	
a. Catalysts increase the reaction rate by reducing the activation energy. b. Enzymes are catalysts that speed up chemical reactions in living organisms.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
	Demonstrate fast and slow reactions such as rusting of iron and burning of steel wool.
Students will measure the rates of chemical reactions that leave a visible end point. Compare the rates of the same reaction when different concentration of reactants are used and when different temperatures are used (safety precautions).	See Sample Lesson 12, the Rate of a Chemical Reaction.
Students will compare the rates of catalyzed versus uncatalyzed reactions; e.g., release of oxygen from hydrogen peroxide with or without a catalyst (safety precautions).	

5. Effect of Surface Area

   a. If the reaction is between a solid and a gas, the only part of the solid that is available for reaction is the surface.
   b. Polishing away corrosion exposes more surface area which speeds up the rate.

B. Collision Theory

1. Effect of Collisions

   a. Most chemical reactions involve collisions between atoms, ions, and molecules.
   b. A single molecule may experience a billion collisions in a second but a very small fraction are effective.

2. Activation energy

   a. Only the molecules on the high energy end of the Boltzman distribution have sufficient energy to form the activated complex.
   b. The activated complex is species formed between two reactants. It has definite bond angles and energies.
   c. A rise in temperature increases the number of molecules with activation energy.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
Students will understand that the proportion of exposed surface area is an important variable in determining reaction rate.	Place a large piece of wood, a wood splint, and sprinkle sawdust in a Bunsen burner flame. Discuss the differences observed.
Students will compare collisions between particles as additional factors affecting rates of reactions.	Demonstrate a slow reaction which will vary with temperature in an ice-water bath, at room temperature, and in a hot water bath.

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
3. Collision Geometry In order to react, molecules must collide with the proper orientation.	
4. Reaction Mechanisms a. A series of steps consisting of two-body collisions is thought to account for the way in which most chemical reactions take place. b. The reaction of hydrogen bromide with oxygen to form bromine and water probably involves a simpler mechanism than is expressed in the balanced equation.	Study possible reaction mechanisms for simple reactions. Identify substances in the rate determining step.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

UNIT XI: EQUILIBRIUM

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Gain knowledge that equilibrium is an essential aspect of chemistry.
- Gain in understanding of the interrelationships of temperature, pressure, and the equilibrium state of chemical reactions.
- Compare various ways of defining acids and bases and the relative advantages of each.
- Understand the relationship between titration and the change in pH.
- Refer to a table of indicators to determine which is appropriate for the measurement of a given pH.

CONTENT: CHEMISTRY

UNIT XI: EQUILIBRIUM

I. Equilibrium occurs in a closed system at constant temperature and is recognized by unchanging macroscopic properties such as color and pressure.

   A. Recognizing Equilibrium

      1. Given the reaction $A + B = C + D$. At equilibrium the rate at which $A + B$ combine to form $C + D$ is equal to the rate at which $C + D$ forms $A + B$.
      2. The equilibrium is dynamic. Forward and reverse reactions proceed simultaneously.

   B. The Law of Mass Action

      1. At equilibrium the product of the concentrations of the products, divided by the concentration of the reactants is equal to a constant.
      2. Each concentration must be raised to a power equal to the coefficient of the substance in the equation.

         Where:

         $aA + bB <=====> cC + dD$

$$K_e = \frac{[C]^c \quad [C]^d}{[A]^c \quad [B]^b}$$

HONORS/ENRICHMENT

The mass action expression can be derived from the rate law.

The K and the mass action expression are only equal at equilibrium.

Ksp can be regarded as a limit and used to predict if a precipitate will form.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 6: Students will gain in knowledge that equilibrium is an essential aspect of chemistry.	Demonstrate a closed vessel containing NO_2. Change the temperature and observe the reaction. $NO_2 + NO_2 \Longleftrightarrow N_2O_4$ (colored) (colorless) Discuss the results.

a. Changing the concentrations does not change the constant. If more of any species is added, all concentrations will change until the numerical value of the constant is the same.

b. Changing the temperature will change the rates of the forward and reverse reactions and therefore the value of the constant.

c. The magnitude of the constant will indicate the degree to which the products or reactants are favored. A value > 1 indicates that products are favored. A value < 1 indicates the reactants are favored.

d. The reciprocal of the constant is the constant for reverse reaction.

C. Le Chatelier's Principle
If a stress is placed on a chemical reaction the equilibrium will shift so as to relieve the stress.

1. Gas phase reactions may be affected by pressure.

2. In heterogeneous reactions some species may have little or no effect.

Le Chatelier's Principle is used to predict the effect of a temperature change on the value of K for an endothermic and for an exothermic reaction.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 3: Students will gain in understanding of the temperature/ pressure at which a chemical reaction achieves equilibrium.	Conduct a demonstration in which a change in temperature/pressure is applied and the measurement of the new equilibrium state is determined.

CONTENT: CHEMISTRY	HONORS/ENRICHMENT
II. Ionic Equilibria - Ionic equilibrium takes place in aqueous solutions and may involve acid-base reactions or the precipitation of a compound.	
A. There are three theories that are used to explain acid-base behavior.	
1. Arrhenius - An acid is defined as a proton donor and a base is defined as an OH^- ion donor.	
2. Bronsted-Lowry a. An acid is defined as a proton donor. b. A base is a substance capable of accepting protons. c. An acid-base reaction consists of a system in which the acid donates a proton to some other species. d. This produces a base out of the acid i.e., a conjugate base and an acid out of the base, i.e., its conjugate acid.	Lewis - An acid is defined as an electron pair acceptor and a base is defined as an electron pair donor. Under this definition water qualifies as a Lewis base but not as a Lewis acid.
B. Strength of Acids and Bases	
1. Strong Acids and Bases a. Those acids and bases that dissociate virtually 100% into ions are regarded as strong acid bases. b. The concentration of ions can be calculated from the original molarity of the solution.	HCl, HBr, HI, HNO_3, $HClO_4$, and H_2SO_4 are strong acids. Group 1 metal hydroxides, $Ca(OH)_2$, $Sr(OH)_2$, and $Ba(OH)_2$ are strong bases.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 6: Students will compare ways of defining various acids and bases and their relative advantages.	Laboratory activities on: Acid/base titration Common acids and bases pH Conductivity and electrolytes.

2. Weak Acids and Bases

   a. This large group of compounds dissociate into ions to a very small degree.
   b. The equilibrium constant for a weak acid is generalized by the following equation.

$$HA \longrightarrow H^+ + A^-$$

$$\frac{[H+]\ [A^-]}{[HA]} = Ka$$

3. The role of water in these reactions should be understood but it need not complicate the equation. An acid will donate a proton to a water molecule resulting in the production of a species with the formula H_3O^+. This species is called the hydronium ion.

C. The dissociation of water and pH

1. Dissociation of Water

   a. Water undergoes a process called autoprotolysis.

$$H_2O + H_2O \longrightarrow H_3O^+ + OH^-$$

   b. The equation for the equilibrium constant is:

$$[H_3O^+]\ [OH^-] = 1 \times 10^{-14}$$

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

c. This equation indicates that both species are always present in aqueous solutions and that if one of the concentrations is known then the other can be found.

d. In pure water the hydronium ion concentration is equal to the hydroxide ion concentration.

$$[H_3O^+] = [OH^-] = 1 \times 10^{-7}$$

2. pH and pOH

a. Values for the hydronium and hydroxide ion can range from very high to very low. A logarithmic notation is used to express these quantities.

b. pH is defined as the negative log of the hydronium ion concentration.

$$pH = -\log [H_3O^+]$$

$$pOH = -\log [OH^-]$$

$$pH + pOH = 14$$

D. Buffers

1. These solutions consist of a weak acid and a weak base.
2. If a strong acid or base is added to such a solution, the pH will change very little.

Dissociation of polyprotic acids - Some acids, such as phosphoric, have more than one replaceable hydrogen and dissociate in steps to form a hydronium ion and an anion.

$$H_3PO_4 \longrightarrow H^+ + H_2PO_4^-$$

$$H_2PO_4^- \longrightarrow H^+ + HPO_4^{2-}$$

$$HPO_4^{2-} \longrightarrow H^+ + PO_4^{3-}$$

Hydrolysis of Salts - The salt of a strong acid and a strong base produce a solution having a pH at or near 7. However, the salt of a strong base and a weak acid such as sodium acetate ion that is produced will bond to a hydrogen ion from the water thus leaving excess OH^- ions in solution.

$$C_2H_3O_2^- + HOH \longrightarrow HC_2H_3O_2 + OH^-$$

The salt of a strong acid and a weak base produce an acidic solution by the following reaction.

$$NH_4^+ + HOH \longrightarrow NH_4OH + H^+$$

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 6: Students will understand the relationship between titration and the change in pH.	Using a pH meter, demonstrate the titration of diprotic and triprotic acids. Students take pH and volume data and plot curves.
Students will be able to refer to a table of indicators to determine which is appropriate for the measurement of a given pH.	Students use a variety of indicators and buffer solutions to determine pH ranges for each indicator.
	See Sample Lesson 13, in which the molecular mass of a compound is determined.

3. A buffer with a pH with less than 7 may be made by mixing a weak acid with a salt of the weak acid.
4. To make a buffer with a pH greater than 7 mix equimolar amounts of weak base with a salt of the weak base.

E. Acid-Base Reactions
Acid-Base Titrations

1. One mole of hydronium ion will react with one mole of hydroxide ion in an analytical procedure known as a titration.
2. In the procedure, the volumes of both are measured with great care and the concentration of either must be known. With the experimental data, the concentration of the unknown solution may be calculated.
3. Indicators are used to change color at a desired pH.

F. For acid-base titrations, the indicator should be picked to change very close to the equivalence point.

1. Strong acid - strong base
2. Weak acid - strong base
3. Strong acid - weak base

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

UNIT XII: SOLUBILITY EQUILIBRIUM

Representative Objectives for the Unit

In accordance with his or present capacities, the student will grow in ability to:

- Understand the meaning of the terms "soluble" and "insoluble."
- Demonstrate ability to predict when precipitation will occur.
- Explain how precipitates may be dissolved.
- Appreciate the importance of buffered systems in chemical reactions and natural processes.

UNIT XII: SOLUBILITY EQUILIBRIUM

I. The principles of equilibrium can be applied to the solubility of salts since nearly all salts are completely dissociated in water.

  A. Even the most insoluble compounds will be in equilibrium with their ions.

  $AgCl_{(s)} \Longleftrightarrow Ag^{+}_{(aq)} + Cl^{-}_{(aq)}$

    1. The equilibrium constant expression for AgCl is:

    $$\frac{[Ag^{+}_{(aq)}]\ [Cl^{-}_{aq)}]}{[AgCl_{(s)}]} = K$$

    2. The concentration of solid is constant and the equation can be written:

    $[Ag^{+}_{(aq)}]\ [Cl^{-}_{(aq)}] = K\ [AgCl_{(s)}]$

    3. Simplifying the equation it becomes:

    $[Ag^{+}_{(aq)}]\ [Cl^{-}_{(aq)}] = K_{sp}$

    4. The smaller the value for similar dissociations, the lower the solubility of the compound.

  B. This equation can be used to calculate:

    1. The equilibrium constant, K.

    2. The solubility product constant, K_{sp}.

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CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 6: Students will gain in their understanding of the meaning of the terms "soluble" and "insoluble."	
MCS 6: Students will demonstrate their ability to predict when precipitation will occur.	

3. The concentrations of the ionic species in a saturated solution.

4. The probability of precipitation if two ionic solutions are mixed.

II. Solubility Product Constants - K_{sp}

A. In a saturated solution of an ionic solid, there are excess solute, the solvent, and ions.

1. The rate of ions going into solution equals the rate at which they are reattached to the solid crystal.

2. In saturated solutions, the product of the ion concentrations (in moles per liter) equals a constant, the solubility product constant, K_{sp}.

3. The value of the K_{sp} depends on which compound is the solute and the temperature of the solution.

4. Experimental data can be used to calculate K_{sp}.

B. Precipitates

1. Tables of K_{sp} values can be used to predict precipitate formation.

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CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
	See Sample Lesson 14, in which the solubility product constant of salt is determined using microscale techniques.
MCS 6: Students will explain how precipitates may be dissolved.	

2. Precipitates are dissolved when adding a reagent produces a species which is removed from the reaction and the equilibrium is upset.

III. The Common Ion Effect and Solubility

A. When a salt, a solid ionic compound, is dissolved in an aqueous solution, such as a weak acid, which contains one of the ions in the salt, the solubility of the salt will be less than in pure water and a buffering effect is produced.

1. A buffered solution is one that resists a change in pH when either hydroxide ions or protons are added.

2. Buffering has many applications; it is very important to living systems.

Discuss and apply the Henderson-Hasselbalch equation:

$$pH = pK_a = \log \left(\frac{[A^-]}{[HA]} \right)$$

B. The common ion effect changes the solubility of a salt.

1. Addition of an ion common to the salt to a solution of the salt reduces the solubility of the salt.

2. Addition of a base can increase the salt's solubility.

Discuss the effect of the addition of ligands to a solution and the formation of stable complex ions to increase the solubility of compounds with low solubility.

$$AgCl_{(s)} \Longleftrightarrow Ag^+_{(aq)} + Cl^-_{(aq)}$$

$$Ag^+_{(aq)} + 2NH_{3(aq)} \longrightarrow Ag(NH_3)_{2(aq)}$$

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 6: Students will appreciate the importance of buffered systems in chemical reactions and natural processes.	Demonstrate how buffers inhibit rapid changes in pH.

UNIT XIII: ELECTROCHEMISTRY

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Understand how electrochemical reactions may be used to produce electricity.
- Balance reduction-oxidation equations.
- Relate the use of electricity to the decomposition of molecules into elements.

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
UNIT XIII: ELECTROCHEMISTRY	
I. Electrochemistry involves reactions where electrons are transferred from one chemical to another.	
A. Oxidation - the loss of electrons and gain a positive charge.	
B. Reduction - the gain of electrons and loss of positive charge.	
In this type of reaction, the same number of electrons gained by one species is lost by the other.	
C. To be balanced a REDOX (a contraction of reduction-oxidation) equation must meet three criteria.	Balance Redox equations by Ion-Electron method.
1. Number of electrons gained = number lost.	
2. Ionic charge must balance.	
3. Number and kind of atoms must balance.	
Oxidation numbers may be used to determine the species gaining and losing electrons. The numbers may be positive, negative, and fractional.	
D. Types of Cells	
1. Electrolytic	
a. An external source of electrons is passed through a circuit, forcing an otherwise non-spontaneous reaction to take place.	

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 13: Students will understand how electrochemical reactions may be used to produce electricity.	See Sample Lesson 15, which shows changes occuring during the oxidation of iron.
MCS 2: Students will relate the use of electricity to the decomposition of molecules into elements.	Show electrolysis of water and show by half-cell reactions what is occuring in each side of the apparatus. Calculate the voltage needed to form hydrogen and oxygen from water.

b. Reduction takes place at the cathode and oxidation at the anode, producing two new chemical species.

c. Practical applications are silver plating for jewelry or chrome plating for automobile trim.

2. Galvanic

a. A spontaneous reaction takes place in which a flow of electrons is produced. The voltage produced may be used to do work.

b. The voltage produced may be calculated using a table of standard reduction potentials.

c. Each cell consists of two half-cells, one in which reduction is taking place and the other in which oxidation occurs.

d. The voltage may be calculated by the following equation:

Calculate the voltage of many half cell combinations using the equation.

$$E^\circ \text{ cell} = E^\circ \text{ reduction} - E^\circ \text{ oxidation}$$

e. The table is constructed from the reference hydrogen half-cell which is assigned the value of zero.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

CONTENT: CHEMISTRY AB	HONORS/ENRICHMENT
3. Everyday practical applications are dry cells that power radios and calculators, and wet cells that start a car.	Calculate the voltage of cells at non-standard conditions using the Nernst Equation. $\Sigma = \Sigma^{o} \quad \frac{0.0592}{n} \quad \log \frac{[E]^{e}\ [F]^{f}}{[A]^{a}\ [B]^{b}}$

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
	Here students measure the voltage of several half-cell combinations and discuss the practicality of these and others for electric automobiles or other applications.

UNIT XIV: THERMOCHEMISTRY AND THERMODYNAMICS

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Understand the importance of chemical synthesis and the accompanying energy changes.
- Relate the relationships between energy transfers and the conditions necessary for chemical reactions to occur.
- Understand that the gain or loss of heat is extremely important in the change of phase of matter.
- Relate heat to its gain or loss and the conversion of heat into work.
- Relate the Kinetic Molecular Theory model to matter around them.
- Understand units of measurement and specific heat.
- Gain in understanding of the relationships of heat, energy, chemical reactions, and work.
- Appreciate the basis of how spontaneous changes can occur.

UNIT XIV: THERMOCHEMISTRY AND THERMODYNAMICS

I. Thermochemistry

A. Chemical changes are accompanied by energy changes. Hydrogen gas burned in oxygen gas will produce water in the gaseous state plus heat.

$$H_{2(g)} + 1/2\ O_{2(g)} \longrightarrow H_2O_{(g)} + 241.8kJ$$

1. Exothermic reactions evolve heat to the surroundings.
2. Endothermic reactions absorb heat from the surroundings.

$$90.7kJ + HgO_{(s)} \longrightarrow Hg_{(l)} + 1/2\ O_{2(g)}$$

B. The Enthalpy Change, delta H,

1. If products have a higher energy than the reactants, energy must be supplied to make the reaction go.
2. If the products have lower energy than the reactants, energy will be liberated when the reaction proceeds.
3. At constant pressure, the heat flow is equal to the difference between the enthalpy of the products and the enthalpy of the reactants.

C. Nature of Enthalpy

1. Only the difference in enthalpy between reactants and products can be measured.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 7: Students will understand the importance of chemical synthesis and the accompanying energy changes.	
MCS 6: Students will relate the relationships between energy transfers and the conditions necessary for chemical reactions to occur.	See Sample Lesson 16, the enthalpy of formation of an oxide.

2. Enthalpy is a phase property and is dependent on the temperature and pressure
3. The magnitude of the enthalpy is proportional to the mass of the substance and dependent upon the phase of the substance.

D. Thermochemical Equations

1. These equations include the heat flow in kilojoules per mole of one of the species.

$$H_{2(g)} + 1/2\ O_{2(g)} \longrightarrow H_2O_{(g)} + 241.8\text{kJ}$$

2. The coefficients always refer to the number of moles. Since enthalpy is a phase function the phase of the substance must be specified. The temperature is assumed to be 25 degrees Celcius unless otherwise stated.

E. Laws of Thermochemistry

1. ΔH is directly proportional to the amount of substance that reacts or is produced in a reaction.
2. ΔH for the reverse of a reaction is exactly the same as the forward reaction but opposite in sign.
3. ΔH is independent of the path followed in a reaction, i.e., ΔH is not dependent on the number of steps involved.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

F. Heats of Formation

1. Changes in enthalpy can be calculated from heats of formation.
2. Heat of formation of a compound is equal to the enthalpy change when one mole of the compound is formed from the elements in their stable forms at 25 degrees C and 1 atm.
3. These values are contained in tables and may used to calculate the change in enthalpy for a chemical reaction by using Hess's Law.
4. The heat of formation for any substance in a stable elementary form is taken to be zero.

G. Hess's Law

$$\Delta H = \Delta H_{formation} \text{ products} - \Delta H_{formation} \text{ reactants}$$

H. Bond Energies

1. Change in enthalpy for reactions in which the reactants and products are gaseous can be calculated from the bond energies.
2. The energy is always positive for bond breaking and negative for bond forming.
3. When weak bonds are broken and strong bonds are formed: $\Delta H < 0$.
4. When strong bonds are broken and weak bonds are formed: $\Delta H > 0$.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

5. Example:

$H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$

$H_{2(g)} \longrightarrow 2H_{(g)}$ $\Delta H = 436$ kJ

$Cl_{2(g)} \longrightarrow 2Cl_{(g)}$ $\Delta H = 243$ kJ

Energy to break bonds = 679 kJ

Energy liberated when 2 moles of HCl formed. -2 x 431 kJ = -862 kJ

Difference -183 kJ/2 moles
- 91.5 kJ/mole

II. Thermodynamics

A. Heat and Temperature

1. Heat is an amount of energy
2. Temperature is the measurement of heat.
3. Various systems exist for the measurement of temperature.
4. Instruments for the measurement of temperature depend on the expansion of matter or changes in electrical conductivity which occur as temperature changes.

B. Specific Heat

1. Different amounts of heat are required to raise the temperature of different kinds of matter.
2. In SI units, specific heat is the energy (in joules) required to raise one kilogram of matter one kelvin or one degree Celsius.

The First Law of Thermodynamics or the Law of the Conservation of Energy:

> "The energy of the universe is constant. If a system undergoes some series of changes that ultimately brings it back to its original state, the net energy is zero."

$\Delta E = q + w$

Delta E (_E) is the change in the internal energy of a system. The internal energy is a property that can be changed by a flow of heat (q), work (w), or both into and out of the system.

$\Delta E = E_{final} - E_{initial}$

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 3: Students will understand that the gain or loss of heat is extremely important in the change of phase of matter.	
MCS 12: Students will relate heat to its gain or loss and the conversion of heat into work.	

4. Specific heat has practical applications for heat storage and insulation.

C. Change of State

1. Heat is required to change matter from one state or phase to another without changing the temperature.
2. Heat of fusion is the energy required to change one kilogram from solid to liquid.
3. Heat of vaporization is energy required to change one kilogram from liquid to gas.
4. Heat of vaporization has practical applications to refrigeration and cooling systems.

D. The Kinetic Molecular Theory

1. Molecules in a liquid are in motion.
2. Some molecules move faster and escape from the surface of the liquid, causing evaporation.
3. The temperature of the remaining liquid is lowered.
4. Molecules at the surface a solid acquire additional energy from their surroundings and they move faster.
5. The additional energy is transmitted to the interior of the solid and it begins to melt.

The Second Law of Thermodynamics in terms of entropy, states that:

> "In any spontaneous process there is always an increase in the entropy of the universe. Nature always moves toward the most probable state available to it. When processes are spontaneous, they result in an increase in disorder. The entropy of the universe is increasing."

Discuss the meaning of the terms in the equation:

$$\Delta S_{univ} = \Delta S_{sys} + \Delta S_{surroundings}$$

and their relationship to temperature, T(K) and the spontaneity of chemical and physical changes.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 3: Students will relate the kinetic theory model to matter around them.	

E. Measurement of Energy

   1. One calorie is the energy required to raise the temperature of one gram of water one degree Celsius. The kilocalorie or Calorie is 1,000 calories. Neither of these units is currently used in scientific work.
   2. The common unit of heat energy used in science is the joule (J). This standard unit represents the energy involved when a force of one newton acts through a distance of one meter.

F. Measurement of Specific Heat

   1. Substances can be heated or cooled with water to determine the heat required to change the temperature of the substance.
   2. A well-insulated instrument in which the temperature measurements are made is called a calorimeter.
   3. The data collected can be used to calculate the specific heat of the substance.

III. Energy for Doing Work

A. Energy Conversions

   1. Living things, machines, and processes which convert one form of energy to another cannot use all of the available energy. Some of the energy is lost as heat.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 12: Students will understand units of measurement of energy and specific heat.	
MCS 9: Students will gain in understanding of the relationships of heat, energy, chemical reactions, and work.	

2. Chemical reactions produce useful work when they are spontaneous and when the work can be used.
3. Examples of chemical reactions which produce useful work are the use of food by living things, combustion, production of electric current, and electroplating of metals.

B. Spontaneous Changes

1. The energy of particles in motion varies. The distribution of motion tends toward randomness. Energy is transferred from particles with higher energy to those with lower energy.
2. Entropy is a term used to describe how energy can be distributed in a system.
3. Spontaneous changes always result in greater entropy--there is an increase in the number of ways the energy can distributed.
4. Only changes in entropy can be measured.

Discuss Gibbs Free Energy and introduce calculations for reactions which cannot be easily done in the laboratory.

Discuss the meaning of the equation and the relationships of the terms in:

$\Delta G = \Delta H - T\Delta S$

Where:

H	S	Outcome
(-)	(+)	Spontaneous at all temperatures
(+)	(-)	Nonspontaneous at all temperatures
(+)	(+)	Spontaneous only at high temperatures
(-)	(-)	Spontaneous only at low temperatures

Discuss the relationship between the standard free energy change (ΔG°) and the equilibrium constant (K) in the equation:

$\Delta G^\circ = -RT \ln(K)$

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 6: Students will appreciate the basis of how spontaneous changes can occur.	

CHEMISTRY AB Weeks Allocated - 1

UNIT XV: NUCLEAR CHEMISTRY

Representative Objectives for the Unit

In accordance with his or her present capacities, the student will grow in ability to:

- Understand the basic concepts of nuclear science.
- Describe how radioactivity can be used to improve understanding of objects around us.
- Distinguish between harmful and beneficial uses of nuclear energy.
- Compare methods of detecting radioactivity.

UNIT XV: NUCLEAR CHEMISTRY

I. Radioactivity

  A. Some atoms are unstable and their nuclei decompose into the nuclei of other elements.

    1. Smaller particles and radiation are also emitted.

      a. An example is the decay of radon, a radioactive gas:

$$^{222}_{86}\mathrm{Rn} \longrightarrow {}^{218}_{84}\mathrm{Po} + {}^{4}_{2}\mathrm{He}$$

Radon atoms with a mass of 222 emit alpha particles (helium nuclei) with 2 neutrons and 2 protons. The product is polonium atoms containing 84 protons and 134 neutrons.

      b. Alpha particles are one type of radiation.
      c. There are approximately 1,500 different nuclei or isotopes among the elements.
      d. 264 isotopes are considered stable or non-radioactive.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 8: Students will understand the basic concepts of nuclear science.	

B. Types of Radiation

TABLE OF TYPES OF RADIATION

Radiation	Approximate Mass (amu)	Charge	Symbol	Type
Alpha	4	2+	He	Particle
Beta	0	1-	e^-	Particle
Gamma Radiation	0	0	γ	Electromagnetic
Neutron	1	0	n	Particle
Proton	1	1+	p(H+)	Particle
Positron	0	1+	e^-	Particle

C. Nuclear Stability and Half-Life

1. Nuclear stability is related to the neutron to proton ratio.
    a. Elements 1-20 are stable when the ratio of neutrons to protons is 1:1.
    b. Heavy elements are stable when the ratio of neutrons to protons is approximately 1.5:1.
    c. Those heavy elements with a ratio above 1.5:1 are beta emitters.
    d. Those with a ratio below 1.5:1 either capture electrons or are positron emitters.
    e. Elements with atomic number 82 and above are unstable and emit alpha particles

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

2. Half-Life

    a. The nuclei of each radioactive element decay into another element.
    b. The time required for one-half of the nuclei to change to those of another element is the half-life.
    c. The half-life of each radioactive isotope of each element can be determined.
    d. An equivalent time is required for the remaining half of the nuclei to decay.
    e. The decay process continues until no more of the original nuclei remain.
    f. The more stable the element, the longer the half-life is.

II. Transmutation

A. Transmuation is the process of changing one element into another.

    1. Transmutation may occur spontaneously through radioactivity.
    2. Transmutation may occur through the capture of a neutron by the nucleus.

B. An example of transmutation occurs in the upper atmosphere when a nitrogen atom captures a neutron.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
	See Sample Lesson 17, which simulates radioactive decay and the determination of half-life. It is also suggested that the half-life of a radioisotope be determined.

1. This reaction is:

$$^{14}_{7}N + ^{1}_{0}n \longrightarrow ^{14}_{6}C + ^{1}_{1}H$$

2. This reaction produces carbon-14 (^{14}C) which is incorporated into living things. After their death, no new ^{14}C is incorporated. The ratio of ^{14}C to the common, non-radioactive isotope ^{12}C, is determined. The amount of remaining ^{14}C and its half-life are used to determine when the organism died. This is called carbon-14 or radiocarbon dating.

III. Nuclear Fission and Fusion

A. Nuclear fission

1. The nuclei of some atoms may be split into smaller atoms when bombarded by neutrons.
2. The process of nuclear fission can be used to liberate great quantities of energy.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 8: Students will describe how radioactivity can be used to improve understanding of objects around us.	
MCS 8: Students will distinguish between harmful and beneficial uses of nuclear energy.	

- a. Nuclear fission is the basis of an atomic bomb when it occurs in an uncontrolled manner.
- b. Nuclear energy can be controlled and used constructively in the production of electrical energy, in medicine, research and in industrial processes.

B. Nuclear Fusion

1. Nuclear fusion is the process of combining atomic nuclei into nuclei of greater mass.

    - a. Nuclear fusion is the process by which stars, such as the sun, produce energy.
    - b. Hydrogen bombs use the principle of nuclear fusion to produce energy.
    - c. There is great interest in developing a process to control nuclear fusion for the production of electrical energy.

2. The nuclear fusion reaction in stars, bombs, and hoped-for electrical power production is:

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{2}_{2}He + ^{1}_{0}n + 1.7^{109}\ \text{kJ/mol (energy)}$$

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

IV. Detection of Radiation

A. Photographic emulsions

1. The exposure of photographic emulsions was the first way that radioactivity was detected.

2. In 1896 Henri Becquerel left some radioactive crystals on his photographic plates which produced an effect as if the plates had been exposed to light. Becquerel is given credit for the discovery of radioactivity.

3. Photographic emulsions are exposed by X-rays in making images of the interior of a body.

B. Geiger-Müller Counters

1. Radiation may produce ions when it strikes other atoms.

2. A G-M detector contains a gas between two charged electrical fields.

3. Radiation passing through the detector produces ions in the gas which permits the electrical potential to discharge.

4. The discharges may be counted to determine the amount of radiation present.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS
MCS 8: Students will compare methods of detecting radioactivity.	

C. Scintillation Counters

1. Radiation striking a phosphor may cause a photon of light to be emitted.
2. The flashes of light may be detected and and counted.

CORRESPONDING SKILLS AND STANDARDS FOR THE STUDENT	LABORATORY/DEMONSTRATIONS

SECTION III:

LESSON PLANNING

LESSON PLANNING
QUESTIONS AND COMMENTARY FOR TEACHING DECISIONS

1. What is the specific objective and how will it be presented to the students?

   The specific objective tells what students will be able to do by the end of the lesson. It should be a refinement of the broader representative objective selected for the lesson from the course description in the Guidelines for Instruction or from the required course of study.

2. What is the value to students in achieving the objective?

   The teacher explains to the students the importance of achieving the objective and how it relates to past or future learning or their total development. The teacher motivates the students by providing a rationale for achieving the objective.

3. What learning activities are suitable for the students involved and for the specific objective being taught?

   The teacher selects or designs initial learning activities--such as a demonstration, a film, a text selection, a lecture, class or small-group discussion, or questions followed by student answers--which fit the ability levels or learning styles of the students. Similarly, the teacher develops initial learning activities which constitute the most efficient means for putting across the particular specific objective.

4. What guided group practice will be provided for the students?

   The teacher has the class perform some of the steps leading toward mastery of the specific objective to determine if the students understand the concepts well enough to perform the tasks independently. Student responses give the teacher feedback on the students' degree of understanding.

5. What independent practice or activity will be provided for the students?

   The teacher gives the students the opportunity to perform the task stated in the objective with little or no teacher assistance.

6. What are the provisions for individual differences in style of learning?

   a. Remedial or Alternatives: The teacher provides other kinds of learning activities for students requiring alternative opportunities to practice the task.

   b. Enrichment or Supplemental Activities: The teacher provides learning activities for students who were successful and can profit from probing the subject to a greater depth or by extending the subject to other areas.

7. How will the lesson be evaluated?

To plan learning activities for future lessons, the teacher assesses students' mastery of the skill or skills of the present specific objective.

The evaluator can be a student, a group of students, or the teacher. An objective test, a subjective test, or a performance test can be used to assess students' ability to perform the objective.

TEACHER RESPONSIBILITIES

The teacher is responsible for creating, maintaining, and fostering a classroom environment and a climate for learning which encourage instructional excellence and achievement. In order to maintain such an environment successfully, the teacher is responsible for:

1. Providing students and parents with a clear statement of instructional objectives, overall goals, and standards of expected progress and achievement.
2. Providing instruction which incorporates a diagnostic-prescriptive program for learning all required skills and concepts.
3. Following the time line as closely as possible, preparing instructional activities for the entire class period, and assisting students in striving for mastery of content and process skills.
4. Having evidence in the classroom of lesson planning to meet the educational needs of the students and the goals of the instructional program.
5. Providing regular instruction and practice in preparing students to take and succeed on tests and other measures of achievement.
6. Maintaining well-defined and consistent classroom standards for academic achievement, citizenship, and work habits.
7. Providing regularly assigned homework designed to reinforce classroom instruction.
8. Providing students and parents with an explanation of the standards used for assigning marks.
9. Providing prompt feedback to students on the results of quizzes, homework, and other class assignments.
10. Recognizing individual student progress and exceptional achievements; displaying student accomplishments and products in the classroom.
11. Recording a minimum of one grade per week in the rollbook for each student.
12. Keeping parents regularly informed of the educational progress and achievement of the student.
13. Informing parents of outstanding progress and accomplishment.
14. Notifying parents of any signs of significant academic decline in student effort or achievement.
15. Providing parents with suggestions on how to help the student study and complete homework assignments.

16. Inviting administrators, department chairpersons, and fellow teachers to visit the classroom and participate in a sharing of effective and innovative lessons.

THE AGENDA

An agenda, or schedule of class activities, prominently displayed in the classroom, gives immediate directions to the students and prepares them for the day's classwork. The agenda should include an objective, a dispatch activity, scheduled class activities, and homework assignment. The agenda may be written on the chalkboard. Some teachers, particularly teachers who travel from classroom to classroom, prefer to use chart paper that can be easily taped or pinned to a board and quickly removed to be used in a new location. A good way to evaluate an agenda is to ask the question, "If a student were absent, could he or she read the agenda and know what happened in the classroom today?"

The dispatch activity is an essential part of the agenda. It should be a short, written, timed exercise that students start as soon as the period begins. Students should be able to complete the dispatch without teacher assistance. The dispatch is used to:

- review and reinforce concepts and ideas previously studied
- start students working immediately upon arrival in class
- preview or introduce new work
- establish a routine
- allow the teacher an opportunity to take care of attendance responsibilities

Below is a sample agenda as it would be written on the board:

AGENDA

Teacher's Name
Chemistry AB, Period 1
April 2, 1989

Objective:	Students will determine the pH of common household substances using teacher prepared standard indicator solutions for comparison; arrange their data; and search for relationships.
Dispatch:	Referring to instructions on the board or handout, use colored pencils to record the color and pH of each standard solution shown in the projected demonstration. Construct a table to record your laboratory data.
Classwork:	Discuss the relationship between hydrogen ion concentration, acidity, and pH. Stress the operational value of an indicator to the chemist.
Independent Work:	Test each household substance with universal indicator. Record your observations.
Homework:	Arrange the substances tested by pH. Write a paragraph describing the relationship between pH and the type of substance as shown by your data.

GUIDELINES FOR ASSIGNMENT OF HOMEWORK*

Homework is a necessary part of each student's educational program. Homework is purposeful when it provides the student with time to complete or expand upon assignments begun in class; develops good work habits and a sense of responsibility for completing tasks on time; and provides opportunities for the student to engage in creative projects, self-directed activities, and research in the area of his or her developing interests. Meaningful homework is related to classwork and the objectives of the course, emphasizes quality rather than quantity, and is consistent with the grade level and maturity of the students.

The following guidelines are applicable to all grade levels:

A. Daily homework assignments are important resources for teachers in helping students learn.
B. Homework assignments should be reasonable in content, length, and resources required. Books and other materials required for assignments should be provided.
C. Homework assignments should be purposeful and clear, based on an analysis of the needs of the class, and modified for students with special needs. It is inappropriate to assign homework as a punishment.
D. Homework may be scheduled over an extended period of time, which may include weekends, as appropriate to course objectives and content.
E. Homework should be directly related to the content and objective being taught. Students should not be given homework assignments they have not been taught how to do. Homework should be assigned to reinforce and enrich student knowledge or extend abilities.
F. Homework assignments and due dates should be thoroughly explained by the teacher in advance and thoroughly understood by the student and parents.
G. When appropriately assigned and explained by the teacher, homework becomes the responsibility of the student to know, understand, complete, and return by the expected due date.
H. Completed homework assignments should be acknowledged and/or evaluated by the teacher and reviewed with students when appropriate.
I. Parents should be notified when students do not complete homework assignments or show signs of significant decline in effort or achievement.

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*Adapted from Revised Guidelines for Assignment of Homework (Los Angeles Unified School District: Office of Instruction, Bulletin No. 22, February 11, 1986).

TEACHING STRATEGIES

A variety of instructional strategies can enhance the students' growth in both concept and skill development. Examples of these instructional strategies include:

- Teacher-directed lesson with the class investigating the same problem.

- Teacher demonstration with the class observing and recording observations and data.

- Independent study. Students conduct independent research and study concept or process areas. When completed, such individual work provides a basis for class learning projects.

- Team learning situations wherein two to four students function together as a laboratory investigation group. Interaction within and among groups acts both as a stimulus and an information-sharing aid to learning.

- Grouping of lower achieving students with those achieving at a higher level. This permits peer tutoring and interaction which can benefit the less motivated or less successful individuals.

- Contract between student and teacher which outlines and prescribes specific tasks to be performed by the student for the fulfillment of certain course requirements and relates levels of achievement to marks earned.

- Self-paced learning designed for mastery. Assessment is conducted as each student concludes each unit, and the results indicate whether a student is ready to advance to the next unit or experience--a repeated opportunity for the instructor to use a new strategy. Student's mark is based on number of units mastered.

- Library research studies wherein many of the principles learned in laboratory and class activities can be applied to a class, small group (team), or individual project.

- Class presentations by individual or laboratory teams on the outcomes of laboratory investigations which are shared with the class.

- Design and formulation of research projects. Individuals or teams apply the methods, material, and techniques learned to a real experimental investigation.

HIGHER LEVELS OF THINKING

Because questioning is the primary tool in achieving educational goals, teachers will want to be sure their questions are appropriate for the ability level of students and challenge students to higher levels of thinking.

Bloom* classifies six levels of thinking. They are:

- Knowledge (recognition or recall of previously learned material)
- Comprehension (translation or interpretation of data)
- Application (application of past learnings to a new situation)
- Analysis (emphasis on the breakdown of material into constituent parts, the detection of relationships, and the organization of parts)
- Synthesis (organization of separate elements in a new creative structure)
- Evaluation (arrival at value judgments about a material or work)

The levels of thinking are sequential. In other words, each category of thinking is different and builds on lower categories. The categories are arranged from simple to complex and from concrete to abstract.

It is important that all students have many opportunities to answer questions involving every level of thinking. Within each category of thinking there are both simple and complex questions for slow and rapid learners.

Questioning is particularly important during guided group practice in the teacher-directed lesson. Carefully constructed questions using various levels of thinking will help the teacher determine the students' comprehension of new material and assess their readiness to move on to independent practice. Individualization of instruction and remedial or alternative work can be achieved by constructing questions of varying levels of complexity.

Verbs alone do not necessarily determine the level of thinking. A given question may not represent the same task to all students. What may be an analysis question to one student may be a knowledge question to a student who has already read and received an explanation of the material. The level of a question depends on how much information the student has already received. If a student is expected to answer a "why" or "how" question by restating an answer provided in the textbook or from the teacher's lecture, the level of thinking is knowledge. If, however, the student has to figure out the answer, not simply remember it, the student is working on a higher level of thinking, such as analysis, synthesis, or evaluation.

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*Benjamin S. Bloom: Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook I: Cognitive Domain, (Longman Inc., New York, 1956).

Six categories of thinking and suggested verbs for teachers are provided below. Teachers will find these helpful in constructing questions and planning lessons. For further classification of learning levels in the affective and psychomotor domains, teachers are referred to *Reaching Higher Levels of Thought*, Los Angeles Unified School District, Office of Secondary Instruction, Publication No. X-118, 1982.

MAJOR CATEGORIES AND SUGGESTED VERBS FOR USE IN STATING COGNITIVE OUTCOMES

KNOWLEDGE

define
repeat
record
list
recall
name
relate
underline

COMPREHENSION

translate
restate
discuss
describe
recognize
explain
express
identify
locate
report
review
tell

APPLICATION

interpret
apply
employ
use
demonstrate
dramatize
practice
illustrate
operate
schedule
shop
sketch

ANALYSIS

distinguish
analyze
calculate
experiment
test
compare
contrast
criticize
diagram
inspect
debate
inventory
question
relate
solve
examine
categorize

SYNTHESIS

compose
plan
propose
design
formulate
arrange
assemble
collect
construct
create
set up
organize
manage
prepare

EVALUATION

judge
appraise
evaluate
rate
revise
score
assess
estimate
choose
measure
select
value

THE PROCESSES OF SCIENCE

The learning and application of the processes and special skills required in science are essential for a complete course. Together with basic skills, knowledge, and attitudes, they provide the foundation for understanding the objectives and content of the course as well as addressing the general societal need for scientific and technological literacy. Students cannot understand the interrelationships of science, technology, society, and individuals without understanding how science happens.

In order to learn the processes and special skills required in science, it is essential that the students participate in content-related, hands-on laboratory investigation. This is the only way to achieve a balance between process and content learning in science.

The processes listed are descriptions of the more important ones. The processes are sequential. Each successive level cannot be accomplished unless the one before has occurred.

PROCESSES		DESCRIPTIONS
Observing	. Seeing . Hearing . Feeling . Tasting . Smelling	The main route to knowledge is through observing, using all the senses. This process is a distinct one by which people come to know about the characteristics of objects and their interactions.
Communicating	. Silent . Oral . Written . Pictorial	Objects are named and events are described by people so that they can tell others about them. Communicating is a fundamental human process that enables one to learn more about a greater range of information than could be learned without this process.
Comparing* (includes measuring)	. Sensory comparisons . Relative positive comparisons . Linear comparisons . Weight comparisons . Capacity comparisons . Quantity comparisons	Comparing is a distinct process by which people systematically examine objects and events in terms of similarities and differences. By comparing the known to something unknown, one gains knowledge about the unknown. All measurements are forms of comparing.

PROCESSES		DESCRIPTIONS
Organizing*	. Data gathering . Sequencing . Grouping . Classifying	Knowledge of principles and laws gained only through the systematic compiling, classifying, and ordering of observed and compared data. Bodies of knowledge grow from long-term organizing processes.
Relating*	. Using space-time relationships . Formulating experimental hypotheses . Controlling and manipulating variables	Relating is a process by which concrete and abstract ideas are woven together to test or explain phenomena. Hypothetical-deductive reasoning, coordinate, graphing, the managing of variables, and the comparison of effects of one variable on another contribute to the attainment of the major concepts of science.
Inferring*	. Synthesizing, analyzing . Generalizing . Recognizing and predicting patterns; stating laws . Formulating explanatory models and theorizing	The process of realizing ideas that are not directly observable is the process of inferring. The process leads to predictive explanations for simple and complex phenomena.
Applying*	. Using knowledge to solve problems . Inventing (technology)	Use of knowledge is the applying of knowledge. Inventing, creating, problem-solving, and determining probabilities are ways of using information that lead to gaining further information.

*These processes include the application of mathematical concepts and skills in interpreting data and solving problems.

LEARNING MODALITIES

The learning modalities are the sensory channels by which students receive information. The three learning modalities are visual, auditory, and kinesthetic. Classroom instruction should include all three modalities.

A student's dominant modality is the channel through which instruction is processed most efficiently. Teachers can capitalize on learning strengths by determining the students' dominant modalities. Teachers should also assess their own learning styles, since research indicates that teachers tend to teach in their preferred modalities. An awareness of different learning styles will assist the teacher in planning a variety of instructional activities.

Some of the materials and techniques listed below have proved highly effective in designing lessons based on learning modalities.

Visual Learners	Auditory Learners	Kinesthetic Learners
Flash cards	Tapes	Tracing activities
Matching games	Music	Tactile experiences
Puzzles	Rhymes	Felt pens
Dictionaries	Clapping/keeping time	Math manipulatives
Card files	Language master	Plays, art
Overhead projector transparencies	Puppet conversations	Puppet actions
Charts	Rhythm instruments	A-V equipment monitoring
Pictures	Poetry	Demonstrator of tasks
Written directions	Reading aloud	Role playing
Instructional books	Talking about the skills to be learned	Pantomime

EVALUATION PROCEDURES

The evaluation of instruction is an integral part of the educational process. It provides information on what has been accomplished and where to go next. The first phase of evaluation should be diagnostic. The teacher should assess what students know before instruction, and then plan an appropriate course of instruction based on students' knowledge and abilities. In addition to diagnostic pretesting, ongoing evaluation during instruction provides teachers with a record of student progress and indicates the instructional changes that may have to be made in order to plan for maximum achievement. Post-testing assesses how well students have met the objectives at the end of the unit or course.

The selection or construction of appropriate instruments of evaluation is critical to the measurement process. Test items must measure and reflect instructional objectives. Tests of achievement and problem-solving skills often require advanced reading skills. Therefore, it is recommended that diagrams, graphs, and pictures also be used to evaluate student progress and achievement.

Various measures of evaluation can be used in all phases of science education. Achievement tests assess science knowledge and comprehension. Problem-solving measures are useful for measuring higher cognitive skills such as analysis, synthesis, and evaluation. Motor skills and skill in the application of scientific knowledge can be evaluated in the laboratory setting. Observation and interview techniques are useful in the assessment of such laboratory skills as manipulating materials, setting up experiments, handling and caring for live specimens, and employing safety practices. These measurement techniques allow for immediate feedback to students.

Suggested assessment procedures include the following: teacher-prepared tests; commercially-prepared tests; departmental tests; informal and formal assessment of individual and group activities in oral work and discussion; and student-prepared test items which provide reinforcement and the opportunity to apply course content.

TIPS FOR PARENTS

The following are some of the important ways in which parents can provide the proper guidance, motivation, assistance, and nurturing home environment for their student's success and learning in science.

1. Show an active interest in your student's learning activities.

   Be a good observer and a good listener. Discuss interests and questions. This will help you learn more about your student's interests, study skills and habits, thinking and reasoning abilities, values, and attitudes.

2. Provide (designate) a quiet work and study area.

   Help your student develop a routine that allows time for homework and study activities.

3. Provide materials for learning.

   For example, try and have related books, magazines, newspapers, dictionaries, encyclopedias, maps, and a globe available for home study. Not only do these help students complete class assignments, but they also motivate and enhance learning and provide opportunities to experience the satisfaction of independent inquiry and discovery.

4. Read, review, and discuss homework and other class assignments.

   Commend efforts and achievements. Make suggestions for improvement, if necessary.

5. Learn together.

   Encourage questions and discussion. Plan activities which provide opportunities for practicing and applying science skills and concepts. For example, help your student learn to withhold judgments until sufficient evidence has been secured, to challenge sources of information, and to be open-minded. These efforts will help lead students toward developing essential critical-thinking and reasoning skills as well as toward guiding and preparing them to become humane, rational, understanding, and participating citizens in a democratic society.

6. Share interests and experiences.

   In order to assist your student to develop a curiosity and interest about science, discuss with him or her science-related articles and television specials.

7. Encourage use of public as well as school libraries.

   Help your student obtain an up-to-date library card and use the library's resources on a regular basis.

8. Plan and make trips and visits to study-related places.

For example, plan visits to museums, open houses at universities, and industrial agencies.

9. Become familiar with the teacher's procedures, routine, and expectations.

It is important to know and understand the teacher's and the school's standards regarding homework, grades, citizenship, behavior, and attendance.

10. Discuss student's progress with the teacher.

Meet and discuss with the teacher, on a regular basis, such concerns as your student's progress and achievement level, his or her specific learning needs which can be met through home study, and how your student might receive individualized help if needed.

11. Become familiar with the school's instructional materials and resources.

Consult with the teacher and librarian about the selection of related books, magazines, newspapers, and other materials available for reading. Also, learn about the variety of other instructional resources used by the school.

12. Learn about the school's academic program.

Parental support of the school program is an essential factor in shaping positive attitudes toward education.

13. Become a resource person.

You may wish to offer your services as a community resource person or suggest other community or business resources which may be of service and enrichment to the school's instructional program.

14. Most of all, care.

It is only through the combined and cooperative efforts of school, parents, and community that the necessary support, strength, enrichment, and continued excellence of our public schools will be sustained.

SAFETY IN THE SCIENCE LABORATORY

Science laboratory investigations are a significant part of science instruction. Every District-approved science course includes laboratory investigations. These investigations enable the student to develop process skills which transcend the facts of science; to integrate the content and laboratory learning; to obtain data which when analyzed, leads to an improved understanding of scientific principles; and to gain an appreciation of science as a process for obtaining and organizing information. The realization of these goals will lead not only to improved science learning but also to an improved understanding of the interrelationships of science and society.

Laboratory experiences are essential in science courses. As with all activities where materials are manipulated, experience has shown that potential hazards exist. It is not suggested that all potentially hazardous materials be removed from school laboratories, rather that teachers must become aware of hazards associated with specific chemicals and take proper safety precautions. Safety is an integral part of science instruction. Only qualified science instructors trained in laboratory procedures and familiar with the potential hazards associated with the substances used in the school's science program should be assigned to teach science courses. Teachers must have sufficient information to use their own judgment about the degree of precaution necessary for using and storing each chemical. Chemicals in any form can be safely stored, handled, or used if the physical, chemical, and hazardous properties are fully understood and the necessary precautions, including the use of proper safeguards and personal protective equipment, are taken.

Chemicals must never be stored alphabetically except within designated categories. Although protective barriers should be present to prevent containers from tumbling from shelves, large, heavy, or breakable containers should be stored near the floor.

Both eye protective devices and chemical resistant aprons should be available. Approved goggles must protect from splash hazard and include only unventilated ones and those with baffled ventilators. Spectacle type eye-protection is not approved. Face shields should be used only with goggles.

Sections 32030 through 32033 of the *California Education Code* deal with devices to protect the eyes.

32030. DUTIES REGARDING EYE PROTECTIVE DEVICES

It shall be the duty of the governing board of every school district, and community college district and of every county superintendent of schools, and of every person, firm, or organization maintaining any private school, in this state, to equip schools with eye protective devices as defined in Section 32032, for the use of all students, teachers, and visitors when participating in the courses which are included in Section 32031. It shall be the duty of the superintendents, principals, teachers or instructors charged with the supervision of any class in which any such course is conducted, to require such eye protective devices to be worn by students, teachers, or instructors and visitors under the circumstances prescribed in Section 32031.

32031. COURSES IN WHICH DEVICES TO BE USED; SUBSTANCES AND ACTIVITIES DANGEROUS TO EYES

The eye protective devices shall be worn in courses including, but not limited to, vocational or industrial arts shops or laboratories, and chemistry, physics or combined chemistry-physics laboratories, at any time at which the individual is engaged in, or observing, an activity or the use of hazardous substances likely to cause injury to the eyes.

Hazardous substances likely to cause physical injury to the eyes include materials which are flammable, toxic, corrosive to living tissues, irritating, strongly sensitizing, radioactive, or which generate pressure through heat, decomposition, or other means as defined in the California Hazardous Substances Labeling Act.[1]

Activity or the use of hazardous substances likely to cause injury to the eyes includes, but is not necessarily limited to, the following:

1. Working with hot molten metal.
2. Milling, sawing, turning, shaping, cutting, grinding, and stamping of any solid materials.
3. Heat treating, tempering, or kiln firing of any metal or other materials.
4. Gas or electric arc welding.
5. Repairing or servicing of any vehicles, or other machinery or equipment.
6. Working with hot liquids or solids or with chemicals which are flammable, toxic, corrosive to living tissues, irritating, strongly sensitizing, radioactive, or which generate pressure through heat, decomposition, or other means.

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[1] *Health and Safety Code*, Sections 28740 et seq.

32032. STANDARDS FOR DEVICES

For purposes of this article the eye protective devices utilized shall be industrial quality eye protective devices which meet the standards of the American National Standards Institute for "Practice for Occupational and Educational Eye and Face Protection" (Z87.1--1968), and subsequent standards that are adopted by the American National Standards Institute for "Practice for Occupational and Educational Eye and Face Protection."

32033. SALE OF DEVICES AT COST TO PUPILS AND TEACHERS

The eye protective devices may be sold to the pupils and teachers or instructors at a price which shall not exceed the actual cost of the eye protective devices to the school or governing board.

LESSON PLAN FORMAT

Subject or Course: Teacher:

Representative Objective:

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing___ Reading___ Listening___ Thinking___

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Synthesis___ Analysis___ Application___ Evaluation___

1. Specific Objective and How Presented to Students:

2. Value to Students in Achieving the Objective:

3. Initial Instructional Activity to Teach Objective to Students:

4. Guided Group Practice:

5. Independent Practice or Activity:

6. Provision for Individual Differences in Ways of Learning:
   a. Remediation or Alternative Activities:
   b. Enrichment or Supplemental Activities:

7. Evaluation:
   a. Summary:
   b. Homework:

SAMPLE LESSON 1: SEEKING RELATIONSHIPS

Course: Chemistry AB Teacher:

Representative Objective: Development fundamental skills necessary for laboratory work in chemistry.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing X Reading X
Listening___ Thinking___

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___
Application X Synthesis___ Evaluation___

1. Specific Objective and How Presented to Students: Students will demonstrate the ability to use basic laboratory equipment to measure the volume and mass of a cylindrical object precisely, look for the relationship between mass and volume, and communicate their findings in properly written laboratory reports.

2. Value to Students in Achieving the Objective: The student will learn the basic skills needed to make quantitative measurements in chemistry.

3. Initial Instructional Activity to Teach Objective to Students: A discussion of significant figures and the limitations of measurement will precede this activity. The teacher will identify common laboratory equipment, demonstrate its proper care and use, and show students how to read various scales as precisely as possible. If necessary the teacher will demonstrate the correct method to read a meniscus and review basic graphing.

4. Guided Group Practice: The teacher will closely monitor measuring procedures by checking student care of equipment and ability to read scales accurately and precisely.

5. Independent Practice or Activity: Students will collect, record, and analyze data seeking a relationship between mass and volume.

6. Individual Differences and Learning Modalities: Since these skills are necessary for successful chemistry laboratory performance, the time allotted for this activity should be determined by the individual ability and previous experience of each student.

   a. Remediation or Alternative Activities: Students who lack prior experience in massing may profit from a practice session before the lab using the balance to mass common lab objects such as a rubber stopper and a small beaker. Sections C and D may be omitted in classes which require more time for basic instruction.

   b. Enrichment or Supplemental Activities: Section D of the exercise is suitable for enrichment or honors classes. Read and report on Archimedes.

7. Evaluation: Students will be evaluated on their ability to collect, record, and analyze data as shown in formal laboratory reports. A lab test to determine the density of an unknown liquid may be used for further evaluation.

LABORATORY EXERCISE IN SEEKING RELATIONSHIPS

Introduction:

Each measured quantity is reported with a certain amount of measurement of uncertainty. Unless otherwise instructed, record all certain digits plus one estimated value. Most chemistry laboratory manuals contain a table which lists uncertainties. If the value is not given, assume that the uncertainty is plus or minus one-tenth of the estimated value.

NOTES TO TEACHER

Advance Preparation:

Metal specimens which will fit into graduated cylinders can be cut from copper, iron, or aluminum rods in the metal shop. Specimen lengths should vary from one-fourth to one-half the length of the graduated cylinder. Stamp each specimen with an identifying number. If glass graduates are used, tell students to minimize breakage by tilting the graduate and slowly slipping the rod down its side.

Experimental Procedure:

1. Construct a data table for each assigned section. If your assignment includes sections A and B only, your table will look like this:

		VOLUME (ml)		
SPECIMEN NUMBER	MASS (g)	Water + Specimen (m)	Water Alone (m)	Specimen Alone (m)

(Data)

2. Choose two metal specimens. Record their data numbers on your data table.

3. Measure the mass and volume of your specimens using the procedures A-D assigned by your teacher.

   A. Massing with a Balance

   Keep balance pans clean and dry. To avoid corrosion do not place liquids or solids directly on the pan. Arrest the pans of your balance after use. Record the mass with its uncertainty for each specimen on your table.

B. Volume by Displacement of Water

Keep the plastic guard at the top of the graduated cylinder to protect the fragile lip. Fill the graduated cylinder approximately one-third full of water. Hold the graduated cylinder at eye level to read the lowest point on the meniscus. Record the volume of water with its measurement of uncertainty on your data table. Add the specimen and record the volume of the water and specimen. Measure and record the volume of the other specimen.

C. Volume by Direct Measurement

Measure the length and diameter of your specimens. Record these quantities with their uncertainties and measurement labels (units).

D. Volume Using Archimedes Principle

Measure the mass of each specimen suspended in water (or another liquid). Record measured values and uncertainties.

4. Collect data for the mass and volume of each specimen measured by your classmates.

Data Analysis:

1. Complete your data tables by calculating the volume of your objects in B and C (use geometric relationships). Recognize the additivity of measurement error and record the uncertainty of these derived values. Archimedes' Principle may be used to calculate the volume of each specimen based on its loss of mass in a given liquid. Ask your teacher to give you the density of the liquid used. Round off all derived quantities to the correct number of significant figures.
2. Which method is the best way to determine the volume of an object? What factors determine which is "best"?
3. Which method is the most precise? How can you determine this?
4. Construct a graph using class data to show the relationship between mass and volume. Record mass on the vertical and volume on the horizontal axis.
5. Does your graph show a relationship?
6. Could you extrapolate your data line to point 0.0 on the graph? Explain.

NOTES TO TEACHER:

Post-Lab Discussion Notes to the Teacher: Discuss the additivity of error in derived values. In addition and subtraction the total uncertainty is the sum of the amount of uncertainty of each value; the uncertainty in multiplication and division problems is equal to the sum of the percent uncertainties. All uncertainties are rounded to a single digit. The best measuring instrument may be the one available, the most convenient, the most precise, the one best suited to the shape and/or size of the object, etc. The most precise instrument is the one which has the lowest percent of uncertainty. Class data should show two groups of points corresponding to the density of the two specimens used. The mass/volume relationship is constant, a direct relationship. Students may need help understanding this concept and in drawing the best straight lines to average class data for each specimen. Once the relationship is established, students should have no problem understanding that the extrapolation will go through point 0.0 (as volume approaches 0, mass approaches 0). You may discuss the concept of density at this point.

Part D is designed for the advanced student.

SAMPLE LESSON 2: REGULARITY - EXPERIMENTAL DESIGN LABORATORY EXERCISE

Course: Chemistry AB   Teacher:

Representative Objective: To improve student ability to observe, organize and recognize patterns.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing_X_ Reading___
Listening_X_ Thinking_X_

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___
Application___ Synthesis_X_ Evaluation___

1. Specific Objective and How Presented to Students: The student will demonstrate the ability to design and perform an experiment, record data in an organized manner, identify patterns in this data, and write a formal laboratory report to test a given question.

2. Value to Students in Achieving the Objective: The student will practice basic laboratory skills problem solving in an experimental design situation.

3. Initial Instructional Activity to Teach Objective to Students: Students will be shown the materials and given the testable question.

4. Guided Group Practice: It is assumed that students have practiced observing, arranging, and identifying patterns in laboratory data during experiments preceding this activity (i.e., observation of a burning candle or match).

5. Independent Practice or Activity: Student pairs will be allowed approximately 45 minutes to complete this activity.

6. Individual Differences and Learning Modalities: During the post-lab discussion, students will compare their experimental designs.

   a. Remediation or Alternative Activities: Students may work together in pairs and complete one laboratory report representing their joint effort.

   b. Enrichment/Supplemental Activities: New testable questions shared during the post-lab discussion can lead to new experimental designs. This activity may be presented as a laboratory practical quiz.

7. Evaluation: Students will be evaluated on their ability to use a given testable question as the basis for designing an experimental procedure to collect, arrange, and analyze data. The final product will be a written report in standard laboratory format.

LABORATORY EXERCISE ON EXPERIMENTAL DESIGN

Introduction:

This experimental design activity can be given either as a laboratory exercise or a practical quiz to evaluate the student's ability to use scientific processes.

Materials:

(for 15 student pairs)
    10g each $CuSO_4$, NaCl (table salt), $CaCO_3$
    10g NaCl mixed with trace of phenolphthalein indicator powder
    10g NaCl mixed with trace of bromthymol blue indicator powder
    1L approximately 1M NaOH (40g NaOH/L distilled water)
    deionized water

(per student pair)
    5 13 x 100mm test tubes
    1 test tube rack (or small beaker)
    1 10ml graduated cylinder
    1 stirring rod
    small scraps of paper

Advance Preparation:

Dispense each salt from clear labeled bottles. Label the salts A, B, C, D, and E. Provide wood splits to scoop small quantities of chemicals onto labeled scraps of paper. NaOH solution should be dispensed from bottles labeled: **CAUTION: "THE LIQUID"**

Safety Precautions:

Students must wear aprons and goggles during this experiment. Warn them to immediately flush any chemical spills with water. Wash hands after the experiment.

Experimental Procedure:

Give students the following oral instructions (if this is not a quiz, omit instruction 1).

1. This is an experimental design quiz. Speak only to your lab partner.
2. Use one sheet of graph paper. Write both partners' names on this sheet.
3. Your laboratory report should include: Purpose, Data, and Interpretation.
4. Design an experiment to answer the question: How many regularities (patterns) can you find using small amounts of the solids, "THE LIQUID," and deionized water? Remember to describe the regularities in your interpretation.
5. HINT: data should be organized in a good communication format.
6. Your paper will be collected at the end of the class period.

Data Analysis:

Expect students to use a standard laboratory report format with emphasis on the following:

1. A well-designed procedure to test the question.
2. Thorough observations reported in a data table (expect observations before and after mixing, water and liquid solubility, color change).
3. An interpretation which groups chemicals which are similar in initial color and/or appearance, that change color in each liquid, that have similar solubility, etc.

SAMPLE LESSON 3: OPEN-ENDED DISCUSSION

Course: Chemistry AB Teacher:

Representative Objective: To enhance student awareness and surface student values about current environmental issues; to improve critical thinking skills; and to promote responsible decision making based on the scientific processes of data collection and analysis.

Sending and Receiving Skill(s) Emphasized: Speaking X Writing ___ Reading ___
Listening X Thinking X

Thinking Level or Cognitive Level: Knowledge ___ Comprehension ___ Analysis ___
Application ___ Synthesis ___ Evaluation X

1. Specific Objective and How Presented to Students: Students will develop an awareness, express their opinions, and listen to the values of their peers on current environmental problems relating to chemistry.

2. Value to Students in Achieving the Objective: The student will recognize responsible decision-making as a responsibility of scientists.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will guide students toward choosing a current environmental topic and provide for acquisition of data necessary for an informed student discussion. The teacher's opinions are not an appropriate part of this discussion.

4. Guided Group Practice: Students will initially discuss several problems to help them surface their opinions about environmental issues.

5. Independent Practice or Activity: Homework assignments require independent reading and writing on environmental issues related to chemistry.

6. Individual Differences and Learning Modalities: Student assignments will be designed to address individual interests and abilities. Students will neither be called upon nor forced to participate in the discussion. The teacher will recognize that some students feel more comfortable expressing their values in written rather than in oral form.

   a. Remediation or Alternative Activities: The teacher may expedite this process by providing several topics, asking for a student vote to choose one, and/or supplying copies of articles on the topic for student use. The teacher can begin the discussion by presenting an issue or "double-edged sword" followed by a discussion question (i.e., Pesticides reduce crop damage by insects; they pollute our water supply. Should all pesticides be banned?)

   b. Enrichment or Supplemental Activities: Television programs may be used to introduce a problem. Encourage students to design posters which represent their views.

7. Evaluation: Students will be evaluated on their ability to collect, analyze, and communicate data (written and/or orally as small group or class discussions) pertaining to a current environmental issue.

OPEN-ENDED DISCUSSION ON ENVIRONMENTAL ISSUES

NOTE TO THE TEACHER

The following is intended for teacher use only. All instructions to the students are to be given orally.

Introduction:

Invite students to share some of their concerns regarding the impact of chemistry on their environment. Ask for both the beneficial and harmful effects of chemistry.

Homework Assignment:

Find a recent article which deals with an issue involving chemistry in the environment (i.e.: air pollution, acid rain, toxic wastes, pesticides, genetic engineering). To prepare for the discussion, students must read the article and bring it to class.

Choosing Discussion Topic:

1. Divide the class into groups of four or five students.
2. Allow 10 minutes for sharing issues within each group. At the end of this time, the group must choose the one issue they feel the most strongly about. List these issues on the board.
3. Each group will choose a spokesperson to give the class a couple of sentences about their topic.
4. Students will individually vote on the issue (listed on the board) which they would prefer to discuss.
5. Allow several days for all students to find, read, and write summary of an article on the topic chosen.

Discussion:

Begin the discussion by asking students one of the questions:

1. How do you feel about ____(their topic)____?
2. What should be done about ......?
3. Who (voters, scientists, government officials) should be given the responsibility to make decisions about ......?
4. How can we weigh the advantages and disadvantages of this problem ......?
5. What impact will our increasing population have on ......?

As you lead the discussion, encourage students to share data from articles to support their opinions or solutions to the problem and to express their values based on this data. The teacher's feelings about the issue are not part of this discussion. Ask students how they can form an opinion if experts differ on the facts presented in the articles.

Writing Assignment: Ask students to write a summary of the classroom discussion including the data presented, opinions and values of other students, and finally their own feelings about this issue.

SAMPLE LESSON 4: THE FORMULA OF A HYDRATE

Course: Chemistry AB Teacher:

Representative Objective: To develop the student's ability to relate chemical formulas to mole calculations they make in the laboratory.

Sending and Receiving Skill(s) Emphasized: Speaking X Writing ___ Reading ___
Listening X Thinking X

Thinking Level or Cognitive Level: Knowledge ___ Comprehension ___ Analysis ___
Application ___ Synthesis ___ Evaluation X

1. Specific Objective and How Presented to Students: The students will be able to determine the formulas of a hydrate.

2. Value to Students in Achieving the Objective: The student will be able to use collected data, analyze that data in a logical way in order to determine the formula of a hydrate.

3. Initial Instructional Activity to Teach Objective to Students: A discussion of the water of hydration should precede the laboratory. Students should be made aware of the necessity to make and collect data carefully. The teacher should warn the students about the burn danger in this experiment. The teacher should instruct students with long hair to rubber band it back.

4. Guided Group Practice: The laboratory set up should be placed in front of the room so that students can see how the equipment is set up.

5. Independent Practice or Activity: The students should practice handling the crucible and cover with tongs before the experiment begins.

6. Individual Differences and Learning Modalities: Additional practice can be provided to students who do not grasp the concept by having them work with students who do.

    a. Remediation or Alternative Activities: Some students may need help with the calculations of this experiment.

    b. Enrichment or Supplemental Activities: Some students may have time to do another hydrate.

7. Evaluation: Students will be evaluated on their ability to successfully calculate the molar ratio of water to anhydrous salt. Student error should be well within 5%.

THE FORMULA OF A HYDRATE

Prelab Discussion

The purpose of this laboratory activity is to determine the formula of a hydrate. Crystals of many ionic substances easily absorb water from many sources such as from the atmosphere. The water molecules are lodged between the positive and negative ions of the ionic salt in a definite arrangement. A hydrate is a crystalline ionic substance made up of a salt and a specific amount of water. The hydrate of magnesium sulfate, for example, is $MgSO_4.7H_2O$.

The formula means that for every magnesium and sulfate ion in the crystal, there are seven water molecules. There is a ratio of 7 to 1, water molecules to positive or negative ions. Hydrates of different salts may have different ratios.

The water may be removed from the crystal by intense heat. If all the water is removed, only the positive and negative ions remain. This product is called an anhydrous salt. Water will not return to the crystal quickly.

In this laboratory investigation you will determine the formula of a hydrate. That is, the ratio of water to anhydrous salt. You will know the formula of the anhydrous salt when you begin the experiment. You will need to calculate the amount of water in the hydrate by heating it in a crucible and measuring the loss of mass.

Procedure

1. Obtain a crucible and cover. Wash the crucible and cover with soap and a brush, rinse, and dry with a paper towel.

2. Set the cleaned crucible and cover on a triangle and ring on a ring stand and heat with a Bunsen burner. The cover should be askew. Heat with an intense heat so that the bottom of the crucible becomes red. Using tongs, remove the cover and crucible from the ring and let them cool with the cover askew on a hot-pad on your lab desk.

3. Find the mass of the dry crucible and cover. Record the mass on the data table.

4. Your teacher will suggest one of several hydrates you can use. Record the name of the hydrate on the data table. Add this hydrate to the crucible until it is about 1/3 full. Find the mass of the crucible, hydrate and cover. Record in the data table.

5. Place the crucible on the triangle and ring and heat gently (cover askew) for about five minutes to drive off most of the water. Then heat intensely for another five minutes. At the end of the heating, using tongs, place the crucible, contents, and cover (askew) on the hot-pad to cool. When the crucible is cool enough to hold in your hand, find the mass of the crucible, cover, and anhydrous salt.

Data Table

1. Mass of crucible and cover = ________________

2. Mass of crucible, hydrate and cover (before heating) = ________________

3. Mass of crucible, anhydrous salt and cover (after heating) = ________________

Data Analysis

1. Determine the mass of the anhydrous salt alone (that is, without the crucible and cover).

2. Determine the number of moles of anhydrous salt present in the crucible.

3. Determine the mass of the water lost by the hydrate to produce the anhydrous salt. (Hint: the difference in the mass between two of the three items in the data table may yield the easiest method of finding the mass of the water lost.)

4. Determine the number of moles of water lost.

5. Find the ratio of moles of water lost to moles of anhydrous salt.

6. For purposes of this experiment assume that the moles of water in the formula of the hydrate is a whole number. Therefore, round the answer in item #5 above to the nearest whole number.

7. Write the formula of the hydrate.

   ________________________ $\cdot$ X H_2O

8. Your teacher will provide you with the accepted value for X in item #7. Find the percentage error.

9. What would happen to the value of X (would it increase, decrease or stay the same?) if you did not drive off all the water in the crystal. Please explain your answer. Show your reasoning.

NOTE TO THE TEACHER:

Material Preparation:

For a class of 30 students:

15 hot-pads (ceramic bathroom tiles work well)
100 g copper sulfate pentahydrate (cover the label on the stock bottle with another label reading "$CuSO_4$ hydrate."
100 g barium chloride dihydrate (cover the label on the stock bottle with another label reading "$BaCl_2$ hydrate."

SAMPLE LESSON 5: MOLARITY

Course: Chemistry AB   Teacher:

Representative Objective: To develop the student's ability to relate a chemical equation with a chemical reaction.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing___ Reading___
Listening_X_ Thinking_X_

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___
Application___ Synthesis___ Evaluation_X_

1. Specific Objective and How Presented to Students: The students will demonstrate the ability to calculate the molarity of an unknown concentration of HCl solution.

2. Value to Students in Achieving the Objective: The student will be able to calculate the moles of a limiting reagent in a chemical reaction.

3. Initial Instructional Activity to Teach Objective to Students: A discussion of the reaction of calcium carbonate with HCl to produce carbon dioxide gas precedes the experiment. Students are encouraged to review the definition of molarity and mole calculations. The teacher may demonstrate the proper folding of filter paper and the proper procedure for filtering. Caution the students about the caustic effects of HCl. Require the use of aprons and goggles.

4. Guided Group Practice: Students will review balancing chemical equations, mole calculations, and molarity. Students will read the instructions and ask questions.

5. Independent Practice or Activity: Students will collect and analyze data in two class periods.

6. Individual Differences and Learning Modalities: Students will compare the results of their experiment with other groups.

   a. Remediation or Alternative Activities: Some students will need help with equation balancing and mole calculations.

   b. Enrichment or Supplemental Activities: Some students may want to devise an experiment to capture and measure the volume of carbon dioxide produced in the experiment.

7. Evaluation: Students will be evaluated on the degree to which they approach the value of the molarity of the HCl solution. They will also be marked on their recognition of the possible sources of error in this experiment.

FINDING THE UNKNOWN MOLARITY OF A HYDROCHLORIC ACID SOLUTION

Introduction:

In this experiment you will investigate the reaction of calcium carbonate, $CaCO_3$, sometimes called marble chips with a hydrochloric solution, $HCl_{(aq)}$. This reaction, like any other reaction, can be expressed in symbol form. The balanced reaction is:

$$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)}$$

Your teacher will assign your lab group a hydrochloric acid solution with an unknown molarity. You are to find the molarity of the acid solution from your experimental observations, data, and calculations.

Materials:

2 - 150 mL beakers
centigram balance
3 g calcium carbonate
20 mL HCl solution
50 mL graduated cylinder
wash bottle
filter paper
watch glass
funnel

Procedure:

1. Find the mass of a clean and empty 150 mL beaker. Record the mass in the data table.

2. Obtain about 3 g of calcium carbonate, $CaCO_3$. Place the solid in the massed beaker, measure, and record the mass of beaker and solid to 0.01 g.

3. Obtain 20.0 mL of the hydrochloric acid solution from the stock bottle your teacher instructs you to use. Use a 50 mL graduated cylinder to measure the acid.

4. Slowly pour the acid solution into the beaker. Observe the reaction. On a hot plate, warm the beaker for about four minutes. Remove the beaker from the hot plate and allow to cool. Allow the reaction to proceed for about 10 minutes more.

5. Weigh a piece of filter paper.

6. Obtain a funnel, properly fold the filter paper and place in the funnel. Place the funnel in a ring attached to a ring stand. Place a dry beaker below the funnel. Filter the solution through the filter paper and allow the excess solid chips to fall into the filter paper. Never allow the filter paper to become more than half filled with solution.

7. Using a wash bottle filled with distilled water, wash out the weighed beaker two or three times. Pour these portions of water into the filter paper.

8. When the liquid has filtered through, place the filter paper into the weighed beaker. Place the beaker with filter paper into your lab locker to dry overnight. Your teacher may suggest that you place the beaker and contents in a drying oven.

9. On the next day, find the mass of the beaker, filter paper, and excess marble chips. Record the mass in the data table.

Data Table:

Mass of clean beaker
Mass of beaker and $CaCO_3$
Mass of filter paper
Mass of beaker, filter paper and excess $CaCO_3$ in step #9

Questions:

1. Calculate the mass of $CaCO_3$ which reacted with HCl in the experiment (HINT: you will have to do some subtracting of data in the table.

2. Calculate the number of moles of $CaCO_3$ which reacted in the experiment.

3. Using the balanced equation in the introduction and your calculations in question #2, determine the number of moles of HCl used in the experiment. The presumption is that all of the HCl reacted.

4. Determine the molarity of the HCl solution from the definition: molarity = moles of HCl / liters of solution.

5. Calculate the % error in this experiment. You need to ask your teacher for the molarity of the HCl.

6. How would a non-reacting impurity in the marble chips affect the calculated molarity of the HCl solution? Would the molarity have been increased, decreased, or remain the same? Briefly explain.

NOTE TO THE TEACHER:

Material Preparation:

For a class of 30 students, prepare three unknown HCl solutions labeled A, B, and C.

200 mL of 1.2M HCl
200 mL of 1.0M HCl
200 mL of 0.8M HCl

Six electric hot plates are sufficient for the class. Heating the beaker with a Bunsen burner is not recommended because students tend to overheat the solution.

SAMPLE LESSON 6: MOLECULAR MODELS

Course: Chemistry AB Teacher:

Representative Objective: To develop student's ability to visualize the shapes of molecules.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing X Reading X
Listening X Thinking X

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___
Application___ Synthesis X Evaluation___

1. Specific Objective and How Presented to Students: The students will be able to construct models of some simple molecules.

2. Value to Students in Achieving the Objective: The students will learn to relate bonding theory to three dimensional models of molecules.

3. Initial Instructional Activity to Teach Objective to Students: A discussion of Lewis structures should precede the laboratory activity. The teacher should explain the bonding capacities of the atoms involved: carbon, oxygen, and hydrogen.

4. Guided Group Practice: The teacher will closely monitor the students as they build the models, especially the molecules that contain multiple bonds.

5. Independent Practice or Activity: The students will draw representations of the molecular models they build.

6. Individual Differences and Learning Modalities: Additional practice can be provided to students who do not grasp the concept by having them work with students who do.

    a. Remediation or Alternative Activities: Some students may need help translating a chemical formula into a model.

    b. Enrichment or Supplemental Activities: Some students may want to build more complex molecules.

7. Evaluation: The students will be evaluated on their ability to make correct models of the molecules provided and draw representative Lewis structures of those molecules.

MOLECULAR MODEL BUILDING

Introduction:

Models help chemists see molecules in three dimensions. In this laboratory activity you will build models of some simple molecules.

The model set used is composed of wooden balls (atoms), sticks (shared pairs of electrons), and springs (used to represent multiple bonds).

Generally, in organic compounds carbon (black ball) will be involved with 4 bonds (the black ball has 4 holes); oxygen (red ball) is associated with 2 shared pairs of electrons and hydrogen (yellow ball) can accept only one bond.

Material Preparation:

15 ball and stick molecular model kits for 30 students

Procedure:

1. Using ball and stick models, build the following molecules:

   H_2
   Cl_2
   O_2
   CH_4
   C_2H_4
   CO_2
   C_2H_6
   C_3H_8
   C_2H_5OH
   CH_3COOH

2. Draw a picture in your lab report of the first five molecules in step #1.
3. Build a butane molecule, C_4H_{10}.

Questions:

1. Draw Lewis structures of all the molecules built in this laboratory activity.
2. Which molecules appear to contain double bonds?
3. In which Lewis structure do you need to represent unshared pairs of electrons, sometimes called lone pairs?
4. Draw Lewis structures of all the isomers of C_5H_{12}. How many isomers are there?
5. List the models built, and using your textbook write the name of each compound next to its formula.

SAMPLE LESSON 7: INVESTIGATING SOME PROPERTIES OF CRYSTALS

Course: Chemistry AB Teacher:

Representative Objective: To develop the student's ability to make careful observations of some physical properties of crystals.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing X Reading X
Listening X Thinking X

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___
Application X Synthesis___ Evaluation___

1. Specific Objective and How Presented to Students: The students will observe melting points, solubility in water and TTE, and conductivity of four solids.

2. Value to Students in Achieving the Objective: The student will be able to differentiate between ionic and molecular crystals.

3. Initial Instructional Activity to Teach Objective to Students: A discussion of molecules and ionic substances will precede the laboratory. The teacher will explain the use of the equipment and conductivity apparatus. Students should wear goggles and follow safety guidelines, especially with matches and candles. Students with long hair should be asked to tie it back.

4. Guided Group Practice: The teacher will carefully monitor the lab proceedings and guide the students through the use of the conductivity "apparatus."

5. Independent Practice or Activity: Students will collect, record, and tabulate data in one class period.

6. Individual Differences and Learning Modalities: Student groups will work through this laboratory at a rate commensurate with their own abilities and experience.

    a. Remediation or Alternative Activities: Some students may need prior practice with focusing the microscope. Others may need help interpreting whether or not a solid is dissolving in the solvent.

    b. Enrichment or Supplemental Activities: Some students may wish to investigate the crystallization of other substances such as copper II sulfate or sugar.

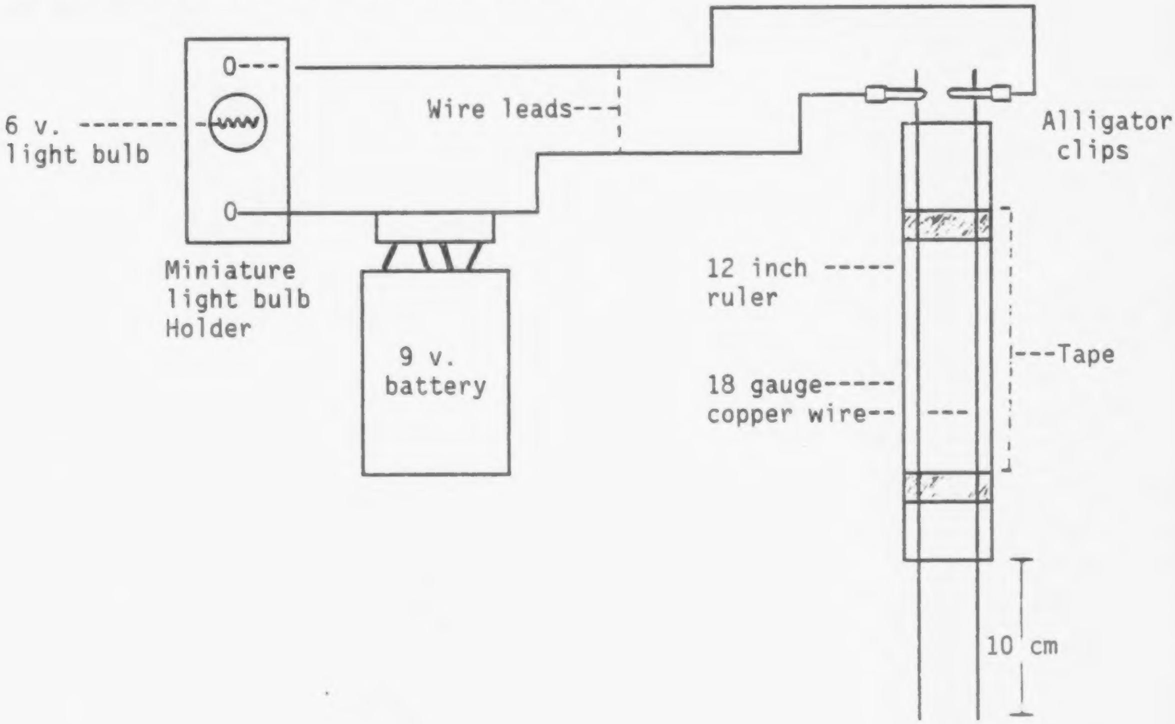
7. Evaluation: Students will be evaluated in their ability to observe, record, and tabulate data. They may also be evaluated in their ability to identify an unknown substance using the same procedure as outlined in the laboratory.

NOTE TO THE TEACHER:

Material Preparation:

Five microscopes should be enough for a class of 30 students. Three conducting apparatus as pictured and described below:

DO NOT use 110 volt AC power source or light bulb.
DO NOT use a variable AC/DC transformer.


6 v. light bulb
Miniature light bulb Holder
9 v. battery
Wire leads
Alligator clips
12 inch ruler
18 gauge copper wire
Tape
10 cm

All items shown are in the District Supply and Equipment Catalog or can be ordered through the Science Materials Center.

INVESTIGATING SOME PROPERTIES OF CRYSTALS

Introduction:

In this experiment you will investigate the nature of some solids. Solids (in the strict sense of the word) are crystalline. The particles that make up the solid are grouped together in a regular pattern.

You will investigate the behavior of four solids. You will test to see if they have high or low melting points. You will investigate their solubility, that is, their ability to dissolve in a solvent. You will study whether or not a water solution of these solids conducts electricity. Finally, you will see what remains when you let a "solution" evaporate.

Materials:

- 0.1 g of each of the following:
  - sodium chloride
  - paradichlorobenzene
  - sugar
  - calcium carbonate
- soup can lid
- candle and matches
- 10 cm square of hard cardboard
- ring stand and ring
- 8 - 125 mm test tubes
- test tube rack
- 100 mL trichlorotrifluoroethane (TTE)
- 100 mL distilled water
- plastic wrap
- microscope slide
- 125 mL beaker
- microscope slide
- 0.1 g oxalic acid (solid)

Procedure:

1. Place a small crystal of each of the following substances on the soup can lid: sodium chloride, paradichlorobenzene, sugar, and calcium carbonate. Separate the four crystals. Place the can lid on a ring attached to a ring stand. Heat the can lid with a candle (first drop some wax on the cardboard square and insert the candle in the puddle until the candle stands alone). **CAUTION**: Do not breathe the vapors coming from the crystals. Paradichlorobenzene vapors are toxic. Record your observations in the data table.

2. Set up 8 test tubes in a test tube rack. Place 2 mL of distilled water into each of four test tubes. Place one crystal of each of the four substances used in step #1 (you may need to get new crystals) into each of the test tubes. Place a small square of plastic wrap over each tube and shake the tube gently. Record the results in the data table. Save the contents of the four test tubes for step #4. Dispose of plastic wrap pieces in the trash, not in the sink.

3. Repeat step #2 but use TTE instead of water.

4. Using the conductivity apparatus set up by your teacher, test the contents of the four test tubes containing water with the conductivity apparatus. Test another test tube containing only distilled water. Record your results in the data table.

5. Place a small drop of the table salt solution on a microscope slide. Smear the salt solution with another microscope slide to make a thin film. Place the wet slide under a microscope set up by your teacher. Observe and record.

6. Place 0.1 g oxalic acid in a small beaker with 5 ml of water. Dissolve the acid by stirring with a stirring rod. Allow the solution to evaporate to dryness overnight. Record your results the next day. You may draw a picture of the bottom of the beaker.

Data Table:

Substance	Melting Point (high or low)	Solubility (yes or no) in water	in TTE	Conductivity (yes or no)
sodium chloride				
paradichlorobenzene				
sugar				
calcium carbonate				
distilled water				

Questions:

1. Which of the substance(s) tested has a low melting point? Which has a relatively high melting point?

2. Which of the substances tested are soluble in water? Which are not?

3. Solutions of ionic substances conduct electricity. Which substance(s) is ionic? Solutions of molecular substances do not conduct. Which substance is a molecular solid?

4. Water is called the universal solvent. Will it dissolve everything? Check your experimental results. Which substances did it dissolve? Which did it not dissolve? How do you know?

5. What is the name and formula of the crystals formed in procedure step #6? Have you ever seen crystals like this before? Explain the situation and results.

SAMPLE LESSON 8: GASES

Course: Chemistry AB Teacher:

Representative Objective: To develop the student's ability to take data on gaseous substances and to make calculations from such data.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing___ Reading___
Listening___ Thinking_X_

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___
Application___ Synthesis___ Evaluation_X_

1. Specific Objective and How Presented to Students: The students will be able to calculate the molar volume of a gas under standard conditions using data obtained in the lab.

2. Value to Students in Achieving the Objective: The student will find that the mathematical laws that have been covered in class apply to real situations in the lab.

3. Initial Instructional Activity to Teach Objective to Students: Students are given outlines of the steps of the experiment they will perform and the laws involved in making calculations (the combined and ideal gas laws, and Dalton's Law of Partial Pressure) are reviewed. Lab safety and related skills will be reviewed by the instructor.

4. Guided Group Practice: Students will be given sample data similar to that they will obtain during the exercise and the students will work out the answer together.

5. Independent Practice or Activity: Students will obtain the necessary materials and will complete the lab in a class period.

6. Individual Differences and Learning Modalities: Additional practice can be provided to students who do not grasp the concept by having them work with students who do.

   a. Remediation or Alternative Activities: Students who have completed the lab calculations can help those who are having difficulties.

   b. Enrichment or Supplemental Activities: Students who seek greater challenge can repeat the experiment with aluminum and try to determine the percent purity of the aluminum in an aluminum soft drink can.

7. Evaluation: Students will determine their percentage error from the accepted value (22.4 L/mol) and student answers to written questions will be marked.

MOLAR VOLUME OF A GAS

Purpose:

The purpose of this investigation is to determine the molar volume of a sample of hydrogen produced by the reaction of magnesium and hydrochloric acid.

Materials Needed: (For each team)

50 mL gas collecting tube
250 mL beaker or larger
15 cm piece of copper wire
5 cm of magnesium ribbon
steel wool
5 mL 6 M HCl
1 metric ruler
ring stand with burette clamp
chemical resistant gloves
For the entire class: one or two 1 liter graduated cylinders

Procedure:

1. Cut a 5 cm piece of magnesium ribbon from the roll and measure its length to the nearest 0.1 cm.

2. Rub the piece of ribbon with steel wool until it is shiny. Roll it into a loose coil and wind a piece of copper wire around it until it is trapped in a loose "cage" of copper.

3. Make sure the cage fits into the bottom of the gas collecting tube and will extend into it about 3 cm while being anchored to the side by a hook on the end of the copper wire.

4. Pour 5 mL of 6 M hydrochloric acid into the bottom of the gas collecting tube. Fill the rest entirely to the top with water.

5. Fill the beaker within an inch of the top with water and have it close to the gas collecting tube. Place the cage in the tube and while covering the mouth with gloved finger, turn the tube over, immerse the mouth below the water level of the beaker and release it. Clamp the gas collecting tube to a ringstand with a burette clamp and observe.

6. While the reaction continues, record the temperature of the water in the beaker, the atmospheric pressure of the room, and the mass of 1 meter of the ribbon (measured by the teacher).

7. When the reaction stops, tap excess bubbles to release them from the cage and sides. Cover the mouth of the tube with your gloved finger again and remove the tube from the beaker, taking care to prevent water or gas from escaping.

8. Carry the tube over to the station with the 1 L graduated cylinder. Carefully place the mouth of the tube below the water surface in the graduate and release your finger from the mouth. Raise and lower the tube until the water level inside the tube and in the graduate are equal. Determine and record the volume of the gas in the tube.

9. Clean up all equipment. The waste chemicals may be disposed of in the drain.

Data:

Mass of 1 meter of Mg ribbon (obtain from the teacher)	
Length of magnesium ribbon	
Mass of magnesium ribbon	
Moles of magnesium	
Volume in liters of H_2 gas formed (measured at room pressure)	
Barometric pressure	
Pressure of dry H_2 gas	
Volume in liters of hydrogen gas corrected to STP	
Moles of hydrogen gas (equal to moles of Mg above)	
Molar volume of H_2 at STP	

Questions:

1. Write a balanced equation for the reaction.

2. Calculate the number of moles of magnesium used.

3. Calculate the number of moles of hydrogen that this amount of magnesium should have formed.

4. Correct the pressure of the hydrogen gas by subtracting the vapor pressure of water vapor at the experimental temperature.

5. Using this corrected pressure and the remainder of your data, determine the volume of the hydrogen gas at STP.

6. Divide this volume in liters by the number of moles of hydrogen to determine the molar volume at STP.

7. Determine the value of R from your data.

NOTE TO THE TEACHER:

SAMPLE DATA:

Temperature	22 C
Mass of 1 meter of Mg ribbon (obtain from the teacher)	.79 g
Length of magnesium piece	4.8 cm
Mass of magnesium piece	.038 g
Volume in liters of H2 gas formed (measured at room pressure)	.0385 L
Barometric pressure	765.2 torr
Vapor pressure of water at room temperature	19.8 torr

Questions:

1. Write a balanced equation for the reaction.

   $$Mg + 2\ HCl \longrightarrow MgCl_2 + H_2$$

2. Calculate the number of moles of Magnesium used.

   .038 g /24.3 g/mol = .0016 mol Mg

3. Calculate the number of moles of hydrogen that this amount of magnesium should have formed.

   .0016 mol Mg x 1 mol H_2 mol Mg = .0016 mol Mg

4. Correct the pressure of the hydrogen gas by subtracting the vapor pressure of water vapor at the experimental temperature.

   765.2 - 19.8 = 745.4 torr

5. Using this corrected pressure and the rest of the data, determine the volume of this hydrogen gas at STP.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad \frac{745.4\text{ torr} \times .0385\text{ L}}{295\text{ K}} = \frac{V_2 \times 760\text{ torr}}{273\text{ K}} \qquad V_2 = .0349\text{ L}$$

6. Divide this volume in liters by the number of moles of hydrogen to determine the molar volume at STP.

$$.0349\ \text{L}/.0016\ \text{mol} = 22\ \text{L/mol}$$

7. Determine the value of R from your data.

$PV = nRT \quad R = PV/nT$

$$R = \frac{\frac{(745.4\ \text{torr})}{760\ \text{torr/atm}} \times .0385\ \text{L}}{.0016\ \text{mol} \times 295\ \text{K}} = \frac{.080\ \text{L atm}}{\text{mol K}}$$

SAMPLE LESSON 9: PHASE CHANGES

Course: Chemistry AB Teacher:

Representative Objective: To develop the student's ability to take data on the energy changes that accompany the changing of a solid to a liquid.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing___ Reading___ Listening___ Thinking X

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___ Application___ Synthesis___ Evaluation X

1. Specific Objective and How Presented to Students: The student will be able to calculate the molar heat of fusion for water using data obtained in the lab.

2. Value to Students in Achieving the Objective: The student will be able to explain why ice water will not get any colder than zero degrees Celsius once equilibrium has been established.

3. Initial Instructional Activity to Teach Objective to Students: Students are given outlines of the steps of the experiment they will perform and the laws involved in making calculations (the definition of a calorie or Joule in terms of energy and conservation of energy) are reviewed. Lab safety and related skills will be reviewed by the instructor.

4. Guided Group Practice: Students will be given sample data similar to that which they will obtain during the exercise and the students will work through the calculations together.

5. Independent Practice or Activity: Students will obtain the necessary materials and will complete the lab in a class period.

6. Individual Differences and Learning Modalities: Additional practice can be provided to students who do not grasp the concept by having them work with students who do.

    a. Remediation or Alternative Activities: Students who have completed the lab calculations can help those who are having difficulties.

    b. Enrichment or Supplemental Activities: Students who seek greater challenge can repeat the experiment this time trying to predict the amount of ice that would be required to bring the temperature of a sample of hot water down to a set temperature, then running the experiment to verify their results.

7. Evaluation: Students will determine their percentage error from the accepted value (1.43 kcal/mol or 5.98 kJ/mol) and student answers to written questions will be marked.

DETERMINING THE MOLAR HEAT OF FUSION OF WATER

Purpose:

The purpose of this experiment is to determine the amount of energy that is absorbed when a mole of ice changes to water at its freezing point.

Materials Needed: (for each team)

styrofoam cup and lid that fits
ice cubes
paper towels
100 mL graduated cylinder
thermometer
balance
Bunsen burner
250 mL beaker
ring stand, ring and iron gauze

Procedure:

1. Determine the mass of an empty, dry styrofoam cup and its cover.
2. Heat some water to approximately 40-45°C and pour about 100 mL into the styrofoam cup.
3. Quickly cover the cup and weigh the system.
4. Measure and record the temperature of the water in the cup.
5. Dry two or three ice cubes with a paper towel, quickly place them in the warm water, and replace the cover.
6. Stir the ice and water until the temperature reaches about 10°C.
7. Record the lowest temperature the system reaches.
8. Remove any excess ice, replace the top, and weigh the system.

Data Table:

1. Mass of dry cup and top	
2. Mass of cup and warm water	
3. Mass of warm water	
4. Initial temperature of the warm water	
5. Final temperature of water	
6. Change in temperature	
7. Final mass of water (after ice had cooled it)	
8. Initial mass of warm water (#3 above)	
9. Mass of ice melted	
10. Moles of ice melted	
11. Energy in Joules lost by warm water (mass x dT x 4.18 J/g°C)	
12. Energy gained by ice water formed as it was heated to final temperature.	
13. Total energy gained by ice sample as it melts at 0° C (#11-#12)	
14. Energy gained per mole of ice (#13/#10)	
15. Molar heat of fusion of water (KJ/mole)	
16. Accepted value	
17. Percent deviation from accepted value	

Questions:

1. Why was the water heated in this experiment when the ice would have melted in room temperature water? Hint: Was the system heat tight?

2. Had the water not been heated, would the final answer for the heat of fusion be too high or too low? Why?

3. Why were the ice cubes dried before adding them?

NOTE TO THE TEACHER:

Data Table:

1. Mass of dry cup and top	35.4 g
2. Mass of cup and warm water	141.2 g
3. Mass of warm water	106.2 g
4. Initial temperature of the warm water	44.5° C
5. Final temperature of water	3.0° C
6. Change in temperature	41.5° C
7. Final mass of water (after ice had cooled it)	
8. Initial mass of warm water (#3 above)	106.2 g
9. Mass of ice melted	55.4 g
10. Moles of ice melted	3.08 mol
11. Energy in Joules lost by warm water (mass x dT x 4.18 J/g°C)	18400 J
12. Energy gained by ice water formed as it was heated to final temp.	695 J
13. Total energy gained by ice sample as it melts at 0 C (#11-#12)	17700 J
14. Energy gained per mole of ice (#13/#10)	5750 J/mol
15. Molar heat of fusion of water (KJ/mole)	5.75 kJ/mol
16. Accepted value	5.98 kJ/mol
17. Percent deviation from accepted value	3.85% error

Questions:

1. Why was the water heated in this experiment when the ice would have melted in room temperature water? Hint: Was the system heat tight? The heat from the water was needed to melt the ice quickly before heat from the outside could create a significant error.
2. Had the water not been heated, would the final answer for the heat of fusion be too high or too low? Why?
   Unmeasured heat from the outside would have helped melt the ice and the answer would have been too low.
3. Why were the ice cubes dried before adding them? Additional unmeasured water would help melt the ice was avoided.

SAMPLE LESSON 10: PROPERTIES OF SOLIDS

Course: Chemistry AB Teacher:

Representative Objective: To develop the student's ability to make observations and record data on solid substances and to make calculations from such data.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing___ Reading___ Listening___ Thinking X

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis X Application___ Synthesis___ Evaluation___

1. Specific Objective and How Presented to Students: The student will be able to categorize a substance by solid type when given a list of properties of the substance.

2. Value to Students in Achieving the Objective: The student will be able to categorize many substances in his or her surroundings and explain their common uses by analyzing the properties they possess.

3. Initial Instructional Activity to Teach Objective to Students: Students are given outlines of the steps of the experiment they will perform and the principles that will be observed. Lab safety and related skills will be reviewed by the instructor.

4. Guided Group Practice: Students will be given a list of terms such as volatility, electrical conductivity, and hardness to define and the teacher will discuss the relationship between bonding strength and these properties.

5. Independent Practice or Activity: Students will obtain the necessary materials and will complete the lab in a class period after first observing the instructor perform the demonstration section of the lab.

6. Individual Differences and Learning Modalities: Additional practice can be provided to students who do not grasp the concept by having them work with students who do.

   a. Remediation or Alternative Activities: Students who have completed the lab questions can help those who are having difficulties.

   b. Enrichment or Supplemental Activities: Students may want to list several substances found in their normal surroundings and categorize them into solid types and giving a rationale for each classification.

7. Evaluation: Students complete answers to written questions and will be able to correctly identify a type of solid when given properties of that substance on a quiz.

PROPERTIES OF SOLIDS LABORATORY

Purpose:

To observe differences in the properties of the four different types of solids.

Materials Needed: (For each group)

four test tubes with corks
sand (SiO_2)
iron nail
paradichlorobenzene ($C_6H_4Cl_2$)
potassium iodide (KI)
TTE (Trichlorotrifluoroethane)

For Teacher Demonstration

four crucibles
conductivity meter
bunsen burner
screw driver with plastic handle

Procedure: (Demonstration by teacher)

Place a sample of each solid in a crucible and test each for the following properties:

A. Electrical conductivity as a solid:

1. Place a sample of each compound in a crucible and test with a conductivity meter.
2. Touch the blade of a plastic handled screwdriver to both wires on a conductivity meter.
3. Have students record observations.

B. Melting point:

1. Place each compound over a bunsen burner and have students measure the amount of time needed to melt each. If they don't melt within 2 minutes, record the high melting point.

C. Electrical conductivity as a liquid

1. Test those substances that melted in Part B with a conductivity meter while they are still molten.

Student Laboratory Procedure:

D. Hardness:

1. Take a small sample (6 mm) of each substance in a test tube. Remove and test each for hardness by touching it and trying to make a depression in it with your fingernail.
2. Record your results.

E. Volatility:

1. Determine whether each of the materials is volatile by determining if each has an odor.
2. Record your observations.

F. Solubility in water:

1. Add 3 mL of water to a sample of each material and shake.
2. Record whether or not the substance dissolves.

G. Solubility in a nonpolar solvents (TTE)

1. Add 3 mL of TTE to a sample of each material and shake.
2. Record whether or not the substance dissolves.

DATA:

Property	Silicon Dioxide	Paradichlorobenzene	Potassium Iodide	Iron
A. Conductivity as a solid				
B. Conductivity as a liquid				
C. Melting point				
D. Hardness				
E. Volatility				
F. Solubility in water				
G. Solubility in nonpolar solvents				

Questions:

1. What do the observations in this exercise indicate about the degree of freedom of electron movement in the four types of solids?
2. What type of bond was affected in each solid as it was heated and changed from solid to liquid?
3. What does the relative hardness tell us about the strength of the bonds in the solids?
4. In which solids were ions present? How do you know?
5. A substance has a high melting point, is brittle, and conducts electricity only as a molten liquid. Which type of bond does it have?

NOTE TO THE TEACHER:

SAMPLE DATA:

Property	Silicon Dioxide	Paradichlorobenzene	Potassium Iodide	Iron
A. Conductivity as a solid	None	None	None	High
B. Conductivity as a liquid	Unable to liquify	None	None	
C. Melting point	High	Low	High	High
D. Hardness	Hard	Soft	Hard	Hard
E. Volatility	Low	High	Low	Low
F. Solubility in water	Insoluble	Insoluble	Soluble	Insol.
G. Solubility in nonpolar solvents	Insoluble	Soluble	Insoluble	Insol.

Questions:

1. What do the observations in this exercise indicate about the degree of freedom of electron movement in the four types of solids? Electrons are able to move freely in metals as solids and in ionic solids when they are melted. Electrons are tightly held in covalent and molecular solids.

2. What type of bond was affected in each solid as it was heated and changed from solid to liquid? Van der Waals forces were broken when the paradichlorobenzene was melted and ionic bonds were weakened when the potassium iodide was melted. The other two substances did not liquify in the lab.

3. What does the relative hardness tell us about the strength of the bonds in the solids? Van der Waals forces are much weaker than ionic, metallic, or covalent bonds so they were the only ones that could be affected by handling.

4. In which solids were ions present? How do you know? Ions were present in ionic and metallic solids because they conducted electricity (though the ionic solid had to be melted first to conduct). If they had not been able to conduct, they would have contained no ions.

5. A substance has a high melting point, is brittle, and conducts electricity only as a molten liquid. Which type of bond does it have? It would be considered to be ionic.

TTE can be ordered from the Science Materials Center.

SAMPLE LESSON 11: SOLUBILITY CURVE OF A SALT

Course: Chemistry AB   Teacher:

Representative Objective: To develop the student's ability to determine the relationship between the amount of a substance that will dissolve in a set amount of water and the temperature of the water.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing___ Reading___
Listening___ Thinking_X_

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___
Application___ Synthesis___ Evaluation_X_

1. Specific Objective and How Presented to Students: The student will be able to make a graph of data obtained in the lab and determine the relationship between solubility and temperature.

2. Value to Students in Achieving the Objective: The student will be able to understand why some recipes used in cooking require the heating of substances in order to dissolve them.

3. Initial Instructional Activity to Teach Objective to Students: Students are given a graph of the solubility curves of several salts. The class discusses the units and techniques of reading three graphs and answers a worksheet dealing with these graphs.

4. Guided Group Practice: The instructor will take one mass of the salt and demonstrate the measurements, safety techniques, and set up of the experiment. The class will then make the required calculations with this data and record it for use in the class data graph.

5. Independent Practice or Activity: Students will obtain different amounts of salt to be dissolved, the necessary laboratory materials, and complete the lab in a class period.

6. Individual Differences and Learning Modalities: Additional practice can be provided to students who do not grasp the calculations by having them work with students who do.

   a. Remediation or Alternative Activities: Students who have completed the lab questions can help those who are having difficulties.

   b. Enrichment or Supplemental Activities: Students may develop a curve for a different substance.

7. Evaluation: Students complete answers to written questions and will be able to answer questions on a test that pertains to a given solubility curve.

SOLUBILITY CURVE OF A SALT

Purpose:

The purpose of this exercise is to determine the effect of temperature on the amount of a salt that will dissolve in water.

Materials: (per group)

1 400 mL beaker
1 large test tube
1 ring stand, ring, wire gauze
1 bunsen burner
1 graduated cylinder
1 buret clamp
1 thermometer
1 copper wire (35 cm long)
NH_4Cl (10-18 g) or KNO_3 (8-35 g)

Procedure:

1. Obtain an assigned mass from the instructor. Each group will be given a specific amount of solid to dissolve. All data for the entire class will be combined to obtain a solubility curve for a range of temperatures.

2. Weigh out the amount of NH_4Cl assigned by the instructor and transfer it to a test tube.
   Add 20 mL of water.

3. Stir the mixture to dissolve as much of the solid as possible.

4. Make a hot water bath in beaker, turn off the heat and position the test tube of NH_4Cl solution in a buret clamp above the the beaker.

   Lower the test tube into the water and stir the solution by moving a loop of copper wire up and down. Be sure the entire sample of solution is below the level of the water in the beaker.

5. Place a thermometer in the solution after all of the solid has dissolved. Raise the test tube out of the water and allow it to cool while continuing to stir the solution. Record the temperature at which a white solid is formed from the solution.

6. Reheat the test tube until all of the solid is dissolved and cool again as a verification of the temperature.

7. Record the data on the board in the appropriate column.

DATA

MASS:	TEMPERATURE:

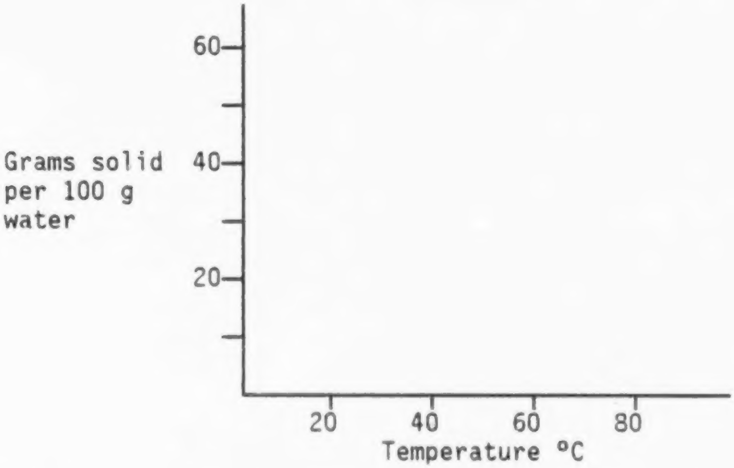
Questions:

1. Correct the value (g solid/20 g H_2O) to the standard units of g solid/100 g of water.

   Example: 12g solid/20g water = Xg solid/100 g water,
   X = 60 g solid/100 g water

2. Record the class data and make the same conversion.

3. Make a graph of the class data with solubility on the ordinate and temperature on the abscissa.



4. Look up the assigned solubility on a solubility curve in a textbook and determine the percentage error between the temperature and that shown on the textbook curve.

   For 70°C, % error = (2°C/70°C) x 100 = 3%

5. In one sentence, state the relationship between solubility of a solid and temperature as found in this laboratory exercise. As the temperature increases, more grams of solid will dissolve.

NOTE TO THE TEACHER:

SAMPLE DATA:

Data: Mass: 12.0 g Temperature: 68°C

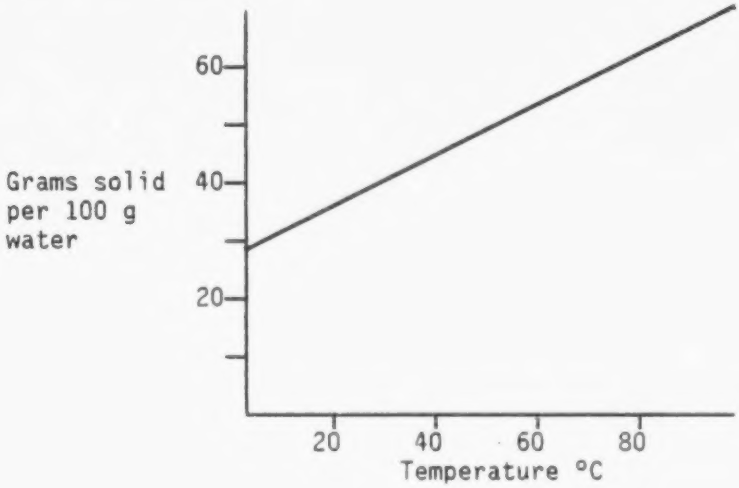
Questions:

1. Correct the value (g solid/20 g H 0) to the standard units of g solid/100 g of water.

   12g/20g water = Xg/100 g water, X = 60 g/100 g water

2. Record your classmates' data and make the same conversion.

3. Make a graph of your class data with solubility on the ordinate and temperature on the abscissa.



4. Look up your assigned solubility on a solubility curve in a textbook and determine the percentage error between your temperature and that shown on the text curve. 70°C % error = (2°C/70°C) x 100 = 3%

5. In one sentence, state the relationship between solubility of a solid and temperature based on this lab. As the temperature increases, more grams of solid will dissolve.

SAMPLE LESSON 12: THE RATE OF A CHEMICAL REACTION

Course: Chemistry AB Teacher:

Representative Objective: Accurately making measurements and analytically determining how temperature and concentration affect the rate of a chemical reaction.

Sending and Receiving Skill(s) Emphasized: Speaking X Writing___ Reading___ Listening___ Thinking X

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___ Application___ Synthesis___ Evaluation X

1. Specific Objective and How Presented to Students: Students will develop an understanding of how a change in the temperature and the concentrations of the reactants will influence the rate of the formation of products.

2. Value to Students in Achieving the Objective: The students will grow in their understanding of the need to make careful measurements, of the importance of working safely in the laboratory, graphing techniques, how temperature influences the rates of chemical reactions, and how changes in concentrations influence the rates of chemical reactions.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will demonstrate the reaction and have students measure the time required for the reaction to take place. The class will discuss the variables which may produce error such as mixing time, dilution of reactants by rinse water, and warming or cooling, out of the temperature range necessary to obtain valid data.

4. Guided Group Practice: Using the necessary equipment, the students will conduct trial runs with the reagents supplied until the times obtained for the reaction are consistent.

5. Independent Practice or Activity: The students will perform experiments on the reactions assigned by the teacher, record the data, perform the necessary calculations, plot graphs using the data, draw conclusions, and provide answers to the questions and calculations at the end of the directions for the activity.

6. Individual Differences and Learning Modalities: The students will report the data on their experimental trials on the chalkboard. The teacher will assess the need for students to review the content and repeat the experiment.

   a. Remediation or Alternative Activities: Students will reread and outline the section in their text on reaction rates. They will repeat the laboratory investigation under the close supervision of the teacher or with the assistance of a successful peer.

b. Enrichment or Supplemental Activities: The students may perform the experiment doing additional trials or changing the variables such as the temperature or additional dilutions.

7. Evaluation: The students will participate in a discussion with the teacher about their experimental results. The graphs which they have drawn will be compared with all other graphs. The students' independent practice papers and their laboratory reports will be marked by the teacher.

THE RATE OF A CHEMICAL REACTION

Purpose:

The purpose of this experiment is to determine how the rate of a chemical reaction is related to the concentration of the reactants and how the change in temperature influences the change in the rate of the reaction.

Safety:

Wear an apron and goggles while working in the laboratory. Wash off any solutions you get on your person immediately. Clean up any spills before you proceed further.

Materials:

test tubes that will hold at least 20 mL
50 mL beakers
thermometers
watch with a sweep second hand
ice bath
hot bath
wash bottle
two-ten mL graduated cylinders
reagents
masking tape

Procedure:

A. Effects of Changes in Concentration

1. The following experiment makes use of the well-known "clock reaction" in which a series of chemical reactions produces a sudden change from a colorless solution to a dark purple color. There are two reagents used, solutions "A" and "B." In part one of the experiment solution "A" will be diluted serially with distilled water according to the following table.

Solution A	Distilled Water	Solution B	Time (sec)	Trial
10mL	0mL	10mL		1
9mL	1mL	10mL		2
8mL	2mL	10mL		3
7mL	3mL	10mL		4
6mL	4mL	10mL		5
5mL	5mL	10mL		6
4mL	6mL	10mL		7
3mL	7mL	10mL		8
2mL	8mL	10mL		9
1mL	9mL	10mL		10

The teacher will indicate which reactions you and your partner should do.

2. To become familiar with the reaction, mark two graduated cylinders with tape and write on them "Solution A" and "Solution B." Fill each cylinder from the appropriate reagent bottle. If only one cylinder is available remember to rinse and dry it between fillings. Divide the labor between you and your partner. One will pour the solutions together into a 50 mL beaker while the other records the length of time for the mixture to turn blue. After the solutions are poured into the breaker swirl the beaker gently to continue the mixing process. Record the time in seconds and duplicate the trial. Do any other combinations assigned by the teacher and record the times. The solutions may be measured into test tubes in advance if graduate cylinders are in short supply or if the solutions must reach another temperature in a water bath.

B. Effects of Temperature

1. Do trial one of the above table to become familiar with the reaction if you have not already done so. Use a thermometer to determine the temperature of the A and B solutions. If the temperatures are not the same, pour the solutions into test tubes and place in a water bath at room temperature. You will now investigate the effect of temperature on the rate of the reaction by allowing the mixture of 10 mL of solution A and 10 mL of solution B to react at a temperature other than room temperature. Measure 10 mL of each solution into separate test tubes and place them in a water bath at or near the temperature designated by the teacher. Place a thermometer in one of the test tubes and monitor the temperature. When the desired temperature is obtained, pour both test tubes into a 50 mL beaker and swirl. Now hold the beaker in the water bath and swirl gently until the change takes place. Record the time to the nearest second. Duplicate the trial at the same temperature.

2. The chemical reactions and explanation for what you observed are as follows. Solution A is 0.02 MIO_3 and provides $IO_3^-{}_{(aq)}$, iodate ion in the reactions. Solution B consists of a mixture of starch and the hydrogen sulfite ion, $HSO_3^-{}_{(aq)}$. In the first step of a two-step reaction:

$$IO_3^-{}_{(aq)} + 3HSO_3^-{}_{(aq)} \longrightarrow I^-{}_{(aq)} + 3SO_4^{-2}{}_{(aq)} + 3H^-{}_{(aq)}$$

As soon as the hydrogen sulfite ions, $HSO_3^-{}_{(aq)}$, are converted to sulfate ions, $SO_4^{-2}{}_{(aq)}$, the iodide ions, $I^-_{(aq)}$ react with iodate ions, $IO_3^-{}_{(aq)}$, to produce elemental iodine, $I_{2(s)}$ by the following reaction:

$$5I^-_{(aq)} + 6H^+_{(aq)} + IO_3^-{}_{(aq)} \longrightarrow 3I_{2(s)} + 3H_2O$$

The starch and the iodine form the familiar blue color signaling that significant quantities of molecular iodine, $I_{2(s)}$ have been produced.

C. Part A and B calculations and questions

1. Part A Calculations

   a. Using the concentration of 0.02 M for solution A, calculate the number of moles of potassium iodate in one mL of solution A.
   b. Calculate the initial molar concentration of potassium iodate in each of the mixtures of 10 mL of solution A and 10 mL of solution B. Initial means the amount available for the reaction after A and B have been mixed.
   c. Plot a graph of the concentration-time data with time on the ordinate, the vertical axis, and the concentration of the potassium iodate in each mixture on the abscissa, the horizontal axis.
   d. Try plotting the data using 1/x vs. time where x is the concentration of potassium iodate in moles/liter.

2. Part A Questions

   a. How are the rate of the reaction and the concentration of the potassium iodate related?
   b. How are the time in seconds and the reaction rate related?

3. Part B Calculations

   a. Using the data generated by you and your classmates, plot the temperature on the abscissa, or horizontal axis, and the time on the ordinate or vertical axis.

   b. How is the time of reaction related to the temperature of the reactants?

4. Part B Questions

   a. Using the graph, predict the length of time required for the reaction at 0 and 50 degrees Celsius.

SUGGESTIONS TO THE TEACHER

PREPARATION OF SOLUTIONS

Solution A

Potassium Iodate - Add 4.3 grams of potassium iodate to enough water to make one liter of solution.

Solution B

0.2 grams $Na_2S_2O_5$, 4.0 grams of soluble starch, and 5 mL of 1.0 M H_2SO_4. To 100 mL of distilled water add the starch and stir until dispersed. Bring 850 mL of distilled water to a boil and slowly add the 100 mL of starch solution. Let cool and add the $Na_2S_2O_5$. Mix thoroughly and let stand 24 hours or until at room temperature. Add sulfuric acid, H_2SO_4, just before use and check the reaction time. The time should be between 10 and 15 seconds for the undiluted solutions. If the reaction requires too much time, add $Na_2S_2O_5$ or a little more acid to solution B. If the reaction requires too little time, dilute solution A.

Students should work in pairs and divide the labor. One student should pour the solutions together and mix while the other times the event. The time should be taken to the nearest second. Only one large clock with a sweep second hand is needed. Most students will prefer to use their own wristwatches with digital readouts.

It is important that students don't contaminate the solutions through accidental mixing. Contamination may start the reaction and give false reaction times. If available, give each pair of students a 25 mL and a 10 mL graduate. The 10 mL graduate is to be used for solution A and the 25 mL will be used for solution B. This will make it easy to dilute solution A as in the procedure. If the graduate cylinders have a removable red plastic base they may be placed in a water bath made from a styrofoam cup for part B.

Part A Suggestions

1. Mix each solution thoroughly and pour into plastic wash bottles.
2. One set for each four students is adequate if the bottles hold 500 mL of solution.
3. Have each pair of students do the first trial in part one to help them understand the experiment.
4. Because the reaction times are less dependable at a dilution of four parts water to one part solution A, it is not necessary to go beyond this point.

Part B Suggestions

1. If there are insufficient numbers of thermometers, students may transfer the solutions to 18 x 150 mm test tubes. Measure the temperature of one of the solutions after they have been in a water bath for five minutes and assume both tubes to be at that temperature.
2. Use the large size styrofoam cups to make water baths.
3. Assign temperatures of 5, 10, 15, 25, and 35 degrees Celsius but none higher or lower. These five trials plus the one at room temperature are adequate to plot the graph.
4. Have crushed ice and hot tap water at 50 degree Celsius to make the water baths.

SAMPLE LESSON 13: MOLECULAR MASS OF A COMPOUND

Course: Chemistry AB   Teacher:

Representative Objective: To assist and develop student's ability to: make measurements and determine analytically the molecular mass of a compound.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing___ Reading___
Listening___ Thinking_X_

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___
Application_X_ Synthesis___ Evaluation___

1. Specific Objective and How Presented to Students: The students will develop an understanding of how neutralization using acid and bases with chemical indicators is used as an analytical procedure.

2. Value to Students in Achieving the Objective: The students will develop an understanding of: determining the molecular mass of a compound, the need to make careful measurements, working safely in the laboratory, the neutralization of acids and bases, and the function of an indicator.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will demonstrate the analytical procedure starting with preparation of solutions, glassware, and burets. The teacher will also explain the relevance of this activity to chemistry in general and this course in particular.

4. Guided Group Practice: The students will be provided with the solutions and equipment to perform a sample titration with a hydrochloric acid solution of known molarity by manipulating burets to deliver the amount of base needed to neutralize the acid solution using phenolphthalein as an indicator. The teacher will lead the students through practice of the needed techniques.

5. Independent Practice or Activity: The student will titrate a solid acid of molecular mass unknown to the student by manipulating burets to deliver the amount of a base needed to neutralize the acid solution using phenolphthalein as an indicator.

6. Individual Differences and Learning Modalities: The students will report data on titrations made during the Guided Group Practice.

    a. Remediation or Alternative Activities: The teacher will assess the students need to repeat the sample titration. If the student shows a lack of understanding, the teacher or a successful student will demonstrate the procedure once again.

    b. Enrichment or Supplemental Activities: Students who finish quickly can be given other samples for analysis.

7. Evaluation: The student will write a report on the experiment in a prescribed form and the teacher will evaluate the students understanding and technique used in the analytical procedure by calculating the percent error.

$$\%\ \text{error} = \frac{(\text{accepted value} - \text{experimental value})}{\text{accepted value}} \times 100$$

THE MOLECULAR MASS OF A COMPOUND

Purpose:

The purpose of this experiment is to determine the molecular mass of an unknown compound, learn the analytical process of titration, and make the measurements used in the calculations.

Safety:

Wear an apron and goggles while working in the lab. Wash off any acid or base you spill on yourself immediately. Clean up any spills before you proceed further.

Materials:

200 mL Erlenmeyer flask
50 mL buret
funnel
buret brush
detergent
phenolphthalein indicator solution
test tube brush
250 mL of 0.20 Molar NaOH solution
200 mL of 0.2 Molar HCl
vial of a solid acid
balance
wash bottle
deionized water

Procedure:

Dissolve a small amount of detergent in a beaker and make a solution. Scrub the glassware to be used in the titration with a test tube brush. Do not use cleansers as they contain abrasives that will scratch the glass. The glass is clean when the water sheets off with out leaving drops on the side of the glassware. Rinse with tap water to remove all traces of detergent.

Obtain a wash bottle and fill with deionized water. Rinse all glassware with about 10 mL of deionzed water, coating the surfaces. Rinse three times with only about 10 mL each time. When rinsing the buret be careful to run rinse water into the tip of the buret each time.

Obtain enough sodium hydroxide, NaOH, to rinse the buret three times with 10 mL portions each time. Run enough NaOH into the tip each time to eliminate bubbles. Now fill the buret with NaOH above the zero line. Drain the NaOH to at least the zero line but do not waste time trying to get the volume at exactly the zero line. Locate the bottom of the miniscus by holding a card behind the buret. Read the buret to the nearest 0.01 mL. If available, fill a second buret with HCl provided by the teacher and read it to the nearest 0.02 mL.

Record the volume of each solution in the laboratory notebook. From the HCl buret add about 25 mL to a clean Erlenmeyer flask. Add three drops of phenolphthalein to the flask and swirl. Now add NaOH until the solution in the flask turns a faint pink color that lasts for about a minute. It is much easier to see the final pink color if the beaker is on a white background. Record the final volumes of each solution and calculate the molarity of the HCl.

mL NaOH X Molarity NaOH = mL HCl X Molarity HCl

Pour the contents of the flask down the sink and rinse with tap water followed by three 10 mL portions of deionized water from your wash bottle. Now repeat the procedure until your calculated molarity for any three trials agree to three significant figures.

To determine the molecular mass of an unknown solid acid, obtain a vial of an unknown sample from the instructor and record the sample number in the laboratory notebook. Find the mass of the vial and sample. Pour some of the unknown sample into a clean Erlenmeyer flask. Ask the teacher for the mass of the sample to be used. Weigh the vial after removing some of the unknown and record the mass in the notebook. Add about 50 mL of deionized water to the solid and swirl it until it dissolves. Add three drops of indicator and titrate with NaOH to a faint pink color. Titrate at least three samples and calculate the apparent molecular mass using the following formula:

$$\frac{\text{Grams of unknown}}{\text{Liters of NaOH x Molarity of NaOH}} = \text{grams/mole}$$

SUGGESTIONS FOR THE TEACHER:

Make the NaOH solution approximately 0.15 molar and standardize it using potassium acid phthalate, molar mass 204.2. Then make several practice solutions of HCl with molarities between 0.10 M and 0.20 M. Each student will need 150 mL of the acid for rinsing the buret and four practice titrations using using 25 to 30 mL per trial. About 300 ml of NaOH per student will give a small reserve if the students who finish earlier titrate more than one solid acid. Dispensing the NaOH into individual bottles helps to prevent waste if students know they won't get any additional solution. The unknown solid acids can be dispensed into small numbered vials. The student can be issued the unknown by rollbook number. The acids listed in the table below are suitable for unknowns. Tell students to start with about 0.3 gram of acid and using a ratio and proportion calculate the mass needed to neutralize a 25 mL portion of the base for the second and all subsequent trials.

ACID SUBSTANCES	GRAMS OF ACID NEEDED FOR 25 mL of 0.15 M NaOH
Potassium hydrogen sulfate ($KHSO_4$, m.m. = 136.2)	0.5
Potassium acid tartrate ($KHC_4H_4O_6$, m.m. = 188.2)	0.7
Potassium acid phthalate ($KHC_8H_4O_4$, m.m. = 204.2)	0.77
Potassium acid oxalate (KHC_2O_4, m.m. = 128.1)	0.5

SAMPLE DATA TABLE

	TRIAL 1	TRIAL 2	TRIAL 3
Final Mass Vial			
Initial Mass Vial			
Mass of Sample			
Final Vol. NaOH			
Initial Vol. NaOH			
Vol. of NaOH			

SAMPLE LESSON 14: THE SOLUBILITY PRODUCT CONSTANT OF A SALT - A MICROSCALE ACTIVITY

Course: Chemistry AB Teacher:

Representative Objective: Accurately conducting laboratory procedures, making observations, recording data, and performing calculations to determine the solubility product of a salt.

Sending and Receiving Skill(s) Emphasized: Speaking X Writing X Reading___
Listening___ Thinking___

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___
Application___ Synthesis___ Evaluation X

1. Specific Objective and How Presented to Students: Students will grow in the understanding of how care in the performance of laboratory procedures, making observations, and the recording and analysis of data can produce information which can be used in similar situations by determining the solubility product constant (K_{sp}) of the salt magnesium carbonate ($MgCO_3$).

2. Value to Students in Achieving the Objective: The K_{sp} of a salt can be used to calculate the maximum concentration of one species if the other is known. This has broad applications in chemistry, particularly in the formation and dissolving of precipitates. Precipitates have great economic importance as important chemical process depend on their formation. Large sums of money are spent to inhibit the formation of precipitates through water conditioning and in the replacement of pipes and appliances damaged by their formation.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will discuss the purpose of the activity and demonstrate the use of the microscale equipment by the use of the overhead projector.

4. Guided Group Practice: The students will lead the students through the performance of an introductory activity using the microscale equipment to gain familiarity with its use.

5. Independent Practice or Activity: The students will perform the experiment using microscale equipment and two reagents. Students will make observations and use these, together with solution concentrations and dilution factors as a basis for calcuations. Students will report using calculations and answers to the questions at the end of the directions for the activity.

6. Individual Differences and Learning Modalities:

   a. Remediation or Alternative Activities: Students will reread and outline the section in their text on equilibrium, precipitation, and the solubility product constant. They will repeat the laboratory investigation under the close supervision of the teacher or with the assistance of a successful peer.

b. Enrichment or Supplemental Activities: The students may perform the experiment using other pairs of reagents which form a precipitate when combined. They may also use these or other procedures to test additional ways of protecting metals from corrosion. These activities are recommended as the basis for a science project.

7. Evaluation: The students will participate in a discussion with the teacher about their experimental results. The percent error will be calculated and, within acceptable limits of accuracy, can be used as a basis for marking. The students independent practice papers and their laboratory reports will also be marked by the teacher.

THE SOLUBILITY PRODUCT CONSTANT OF A SALT

Purpose:

The purpose of this activity is to determine the results of the use of serial dilutions of two reactants in determining the solubility product constant (K_{sp}) of the salt magnesium carbonate ($MgCO_3$) which is formed as a precipitate when they are mixed. When magnesium carbonate ($MgCO_3$) dissolves in water it undergoes the following ionization:

$$MgCO_{3(s)} \Longleftrightarrow Mg^{2+}_{(aq)} + CO^{2-}_{3(aq)}$$

Materials:

0.1 M magnesium sulfate in microscale pipettes
0.1 M sodium carbonate in microscale pipettes
distilled water
96-well microplate
2 transfer pipettes
black paper
microscale stirrer

Procedure:

1. Place the microplate on the black paper so that the row indicator letters (A-G) are on the left and the numerals 1-12 are at the top.

2. Place five drops of water in each of the wells from 2 through 12 in row A.

3. Place five drops of 0.1 sodium carbonate in each of the wells from 1-12 in row B.

4. Add 10 drops of 0.1 magnesium sulfate in well 1, row A.

5. Add five drops of 0.1 M magnesium sulfate in well 2, row A.

6. Mix well 2, row A completely.

7. Transfer five drops from well 2, row A and mix with the water in well 3. Continue the serial dilution procedure to well 12.

8. Discard five drops from well 12, row A. The final concentration of Mg^{2+} ions in well 12 is 0.000045 M.

9. The solutions of the two reagents in the pairs of wells in rows A and B are mixed using row B as the mixing site. After mixing, the final concentration of the reactants will be halved.

10. Note the first well which does not show precipitation. This is the point at which the concentration of both species becomes too low for precipitation to occur. Review the definition of K_{sp}.

11. Calculate the concentration of Mg^{2+} ions in the well determined in step 10.

12. Using the formula $K_{sp} = [Mg^{2+}] \times [CO_3^{2-}]$, calculate the K_{sp} of magnesium carbonate.

13. Using a reference, find the accepted value for the K_{sp} of this salt.

14. Using the accepted value and your value for the K_{sp} of this salt calculate the percent of experimental error using the formula:

$$\% \text{ error} = \frac{\text{accepted value} - \text{experimental value}}{\text{accepted value}} \times 100$$

Questions:

1. In step 6 of the procedure, the solution is 0.05 M in the Mg^{2+} ion. Why?

2. In step 8 of the procedure, five drops are discarded. Why?

3. In step 9 of the procedure, the final concentration of the reactants is halved. Why?

4. In step 10 of the procedure, which well did you indicate?

5. In step 11 of the procedure, what concentration of the Mg^{2+} did you calculate?

6. In step 12 of the procedure, what was your calculated K_{sp} of magnesium carbonate?

7. In step 13 of the procedure, what is the accepted K_{sp} of magnesium carbonate?

8. In step 14 of the procedure, what was your calculated percent error?

SUGGESTIONS TO THE TEACHER:

Microscale chemistry equipment is available from the Science Materials Center on a special order form. A microscale laboratory guide has been District adopted for use in chemistry classes. Professional development opportunities in microscale techniques are periodically conducted by the Office of Instruction.

SAMPLE LESSON 15: THE OXIDATION OF IRON

Course: Chemistry AB Teacher:

Representative Objective: Accurately making measurements and recording observations, in determing factors involved in the oxidation of iron.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing___ Reading___ Listening X Thinking X

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___ Application X Synthesis___ Evaluation___

1. Specific Objective and How Presented to Students: Students will develop an understanding of how the presence of various ions in solution and additional metals will influence the oxidation of iron. This activity can serve as an introduction to content dealing with oxidation-reduction reactions.

2. Value to Students in Achieving the Objective: The students will grow in their understanding of the need to make careful observations, record data, and draw conclusions. Students should appreciate that the oxidation, or corrosion of metals, is of major economic importance. Not only are there major costs in the loss and replacement of metals, but there are additional expenses involved in the application of ways to protect them.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will discuss the purpose of the activity, demonstrate one reaction in part A, and discuss the proper procedures for both parts A and B.

4. Guided Group Practice: The teacher demonstrates the procedures for parts A and B while the students take notes and ask questions.

5. Independent Practice or Activity: The students will perform the experiments in part A using the reagents provided by the teacher and on part B using the procedure given, record the data on two tables, draw conclusions, and provide answers to the questions and calculations at the end of the directions for the activity.

6. Individual Differences and Learning Modalities:

   a. Remediation or Alternative Activities: Students will reread and outline the section in their text on oxidation. They will repeat the laboratory investigation under the close supervision of the teacher or with the assistance of a successful peer.

   b. Enrichment or Supplemental Activities: The students may perform the experiment with other metals. They may also use these or other procedures to test additional ways of protecting metals from corrosion. These activities are recommended as the basis for a science project.

7. Evaluation: The students will participate in a discussion with the teacher about their experimental results. The data table and conclusions will be reported on. The students independent practice papers and their laboratory reports will also be marked by the teacher.

OXIDATION OF IRON

Purpose:

The purpose of this activity is to determine the effect of various ions in the oxidation of iron and to investigate one way in which oxidation may be prevented.

Materials:

1 piece of sandpaper or steel wool
5 test tubes
9 iron nails
1 set of 5 reagents; set X, Y, or Z
5 pieces of pH indicator paper
1 dropper bottle containing 0.1 M potassium ferricyanide solution, $K_2Fe(CN)_6$
1 reagent bottle containing ferrous sulfate solution
100 mL powdered agar or pre-prepared agar melted in a water bath on a hot plate
1 dropper bottle containing 0.1% phenolphthalein solution
1 pair of pliers
3 cm of bare copper wire
3 cm of thin zinc strip, approximately 3-5 mm wide
2 petri dish halves

Procedure:

First Day

Part A - Reaction of Iron with Aqueous Reagents

1. Polish five nails and carefully slide one into each test tube.

2. Just cover the nail in each test tube with each of the reagents in set X, Y, or Z.

   The 0.1 M reagents in each set are:

Set X	Set Y	Set Z
KOH	$Na_2C_2O_4$	$Na_2Cr_2O_7$
Na_2CO_3	$Na_2C_2O_4$	$Na_2Cr_2O_7$
KNO_3	$NaSCN$	$NaCl$
HNO_3	H_2SO_4	HCl
H_2O	H_2O	H_2O

3. Using litmus or other indicator paper, determine whether each solution is acidic, basic, or neutral. Record the data.

4. Allow the nails to stand overnight in the solutions and go to part B.

Part B. Reactions with Two Metals

1. Following instructions given by your teacher, prepare 100 mL of an agar mixture or use 100 mL of an agar mixture which has already been prepared.

2. If your teacher has not already done so, add about 5 drops of 0.1 M potassium ferricyanide and 3 drops of 0.1% phenolphthalein solutions to the agar mixture. Stir thoroughly and let cool.

3. Polish 4 nails. Bend one nail at least 90° with a pair of pliers. Place one straight nail and the bent nail on each side of a petri dish. Make sure the nails do not touch.

4. If the copper wire has a clear coating or is not clean, sandpaper it. Twist the bare piece of copper wire around a nail. Remove the nail and tighten the coil of wire so that good contact is made when the nail is reinserted. Repeat the procedure using the last nail and the zinc strip. Place the copper and zinc wrapped nails on each side of a petri dish. Make sure the nails do not touch.

5. When the agar mixture has cooled to lukewarm and is still fluid, carefully pour it into the petri dishes until the nails and metal wrappings are covered.

6. Make observations during the time remaining in the class period and record the data. Allow the petri dishes to stand overnight.

Second Day

Part A - Prepare and complete a data table

1. Observe and record any changes that have taken place.

2. To each of the five solutions add two drops of 0.1 M potassium ferricyanide solution, $K_2Fe(CN)_6$, which contains the ions $K^+_{(aq)}$ and $Fe(CN)_6^{3-}{}_{(aq)}$.

3. Observe any change. Compare your results with those of students using the other sets of reagents. Record observations from the use of all three sets of reagents in tabular form.

4. Add 1 drop of 0.1 M potassium ferricyanide solution to about 1 mL of ferrous sulfate solution.

5. Compare the result to that obtained when the potassium ferricyanide was added to the various solutions containing nails.

6. Based on your data table, form and record conclusions made from the tests done in step 2 with $K_2Fe(CN)_6$.

Answer the following questions:

1. List the reagents used in part A in which no indication of corrosion was observed.

2. List the reagents used in part A in which there was an indication of corrosion.

3. In part B, what did you observe at the head, the point, and the bend in the nail that was different from the rest of the nail. What might this have to do with the way nails are made?

4. Write an equation for the reaction in which ferrous ions react with potassium ferricyanide to form a colored precipitate.

5. In part B, how are the colors formed, which indicates the site of oxidation, and which indicates the site of reduction?

6. Write the oxidation and reduction reactions for each experiment in part B where a change was observed.

7. Examine a table listing the activity of metals and predict another metal that is more readily oxidized than iron and will protect it from corrosion.

8. What is galvanized iron and how is the iron protected from corrosion?

9. Explain why magnesium rods are used in water heaters.

SUGGESTIONS TO THE TEACHER:

A significant saving in class time can be made by the preparation of the agar mixture in advance. Once prepared, the agar mixture can be kept molten for student use in a water bath on a hot plate. Whether done by the teacher or students, the agar mixture is prepared as follows:

> For each 100 mL of agar mixture, heat about 100 mL of distilled water to a gentle boil. The use of a hot plate is recommended as the heat is distributed better. Remove from the heat and stir in 1 gram of powdered agar. Resume heating and stir until the agar is dispersed.

Each petri dish half will require abut 25 mL of the agar mixture. The additional agar given in the procedure is for the possibility of mistakes or spills. Unused agar mixture can be autoclaved in screw-capped bottles and kept until the next time the activity is done. Be sure to keep the caps loose until the bottles are cool and autoclave for approximately 15 minutes at 15 p.s.i.

SAMPLE LESSON 16: ENTHALPY OF FORMATION OF AN OXIDE

Subject or Course: Chemistry AB　　　　Teacher:

Representative Objective: To assist and develop the student's ability to make measurements and determine analytically the amount of energy liberated when one mole of magnesium combines with one half mole of oxygen gas to form one mole of magnesium oxide.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing___ Reading___
Listening___ Thinking X

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis___
Application___ Synthesis___ Evaluation X

1. Specific Objective and How Presented to Students: The students will develop an understanding of how enthalpies of chemical reactions can be added to obtain the enthalpy for a reaction which is the sum of the others.

2. Value to Students in Achieving the Objective: The students will develop an understanding of: Hess's Law of additivity of heats of reaction, the need to make careful measurements, and working safely in the laboratory.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will demonstrate how two chemical equations can be added together to produce a third equation in the same way two algebraic equations can be added to produce a third. The teacher can add the three reactions involved in the experiment to show how they add up to the reaction for the oxidation of magnesium to magnesium oxide.

4. Guided Group Practice: The students will perform the experiment while directed by the teacher.

5. Independent Practice or Activity: The student will repeat the experiment using different amounts of reactants.

6. Individual Differences and Learning Modalities: The student will make the calculations and report the results to the teacher.

   a. Remediation or Alternative Activities: The teacher will assess the student's need to repeat the experiment and, if necessary, the teacher will demonstrate the aspects not grasped by the student.

   b. Enrichment or Supplemental Activities: Students may repeat the experiment using another metal.

7. Evaluation: The student will write a report on the experiment in a prescribed form and the teacher will evaluate the student's understanding and technique used in the experiment by checking the percent error as calculated by the student.

$$\% \text{ error} = \frac{\text{(accepted value - experimental value)}}{\text{accepted value}} \times 100$$

ENTHALPY OF FORMATION OF AN OXIDE

Purpose:

The purpose of this experiment is to determine the enthalpy of formation of MgO in the following reaction.

Reaction (1)

$$Mg_{(s)} + 1/2\ O_{2(g)} \longrightarrow MgO_{(s)} + \text{heat}$$

This may be done by measuring the change in temperature as Mg metal and MgO react with hydrochloric acid. By adding the correct chemical reactions and their enthalpies with the proper signs, the enthalpy of formation of MgO may be calculated.

Safety:

Wear an apron and goggles while working in the lab. Wash off any acid spills immediately. Clean up any spills before proceeding further.

Materials:

200 mL of 1.0 M HCl
1.0 gram of MgO
0.50 gram of Mg
thermometer
styrofoam cup
balance
100 mL graduated cylinder

Procedure:

1. Find the enthalpy of formation for the following reaction (reaction 2).

$$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow Mg^{2+}{}_{(aq)} + 2Cl^{1-}{}_{(aq)} + H_{2(g)} + \text{heat}$$

2. Add 100 mL of 1.0 M HCl to the styrofoam cup and measure the temperature to the nearest 0.2 degrees C. Record this as the initial temperature in your notebook. Find the mass of the magnesium ribbon to the nearest .01 gram. Use approximately 0.5 gram. Wad the ribbon up into a ball and add it to the hydrochloric acid in the cup. Stir the contents of the cup gently with the thermometer. When the Mg ribbon is completely reacted, measure the highest temperature reached and record the value as the final temperature for that reaction. Rinse the thermometer using tap water and pour the contents of the cup down the drain, rinsing both cup and sink with liberal portions of tap water.

3. Measure 100 mL of 1.0M HCl into the C cup and determine the temperature to the nearest 0.2 degree C. Place a piece of weighing paper on the balance pan and determine its mass to the nearest .01 gram. Add 1.00 gram of mass to the beam of the balance and add solid magnesium oxide to the paper until it just balances. Add the MgO to the HCl and stir gently until the temperature starts to fall. Record the highest temperature reached by the mixture.

   Reaction (3):

   $$MgO_{(s)} + 2HCl_{(aq)} \longrightarrow Mg^{2+}_{(aq)} + 2C^{1-}_{(aq)} + H_{2(g)} + \text{heat}$$

   Clean the thermometer and cup with ample water and put them away.

Calculations:

1. To calculate the number of kiloJoules produced in Reaction (2), use the following equation.

   $$\frac{\text{mass of HCl x change in temperature x 4.18J/gram°C}}{\text{1000J/kJ x moles of Mg}} = \text{kiloJoules produced}$$

2. To calculate the number of kiloJoules produced in Reaction (3), use the following equation.

   $$\frac{\text{mass of HCl x change in temperature x 4.18J/gram°C}}{\text{1000J/kJ x moles of MgO}} = \text{KiloJoules produced}$$

3. Rewrite the equations for reactions 2 and 3 above and replace the word heat with the number of kiloJoules calculated from the data.

4. Reaction (1) shows that MgO is a product and that when adding reactions together, MgO should be on the products side of the sum of the reactions. This means that the reverse of reaction (3) must be used. Add the reverse of reaction (3) to reaction (2). After canceling the like species on each side of the equation, that which is left is not reaction number (1). One more reaction must be added to get the oxygen, $O_{2(g)}$, the hydrogen, $H_{2(g)}$ and water, H_2O to total correctly. Using a textbook, find the following equation that will complete the reaction allowing the hydrogen and the water to add to zero.

Reaction (4):

$$H_{2(g)} + 1/2\ O_{2(g)} \longrightarrow H_2O_{(1)} + 268\ \text{kJoules}$$

This reaction is determined from a reference source because it proceeds with explosive violence and there is no practical way to carry out the reaction in a safe manner in a high school chemistry lab.

5. Add reaction (4) to the sum of reaction (2) and the reverse of reaction (3). Now transfer all energy values to the products side of the equation, paying attention to the signs. This is the thermoequation for the burning of magnesium metal in oxygen to produce magnesium oxide.

SAMPLE LESSON 17: NUCLEAR CHEMISTRY

Course: Chemistry AB Teacher:

Representative Objective: Accurately recording observations and organizing data and ideas in ways that improve their usefulness.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing X Reading___
Listening___ Thinking___

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Analysis X
Application___ Synthesis___ Evaluation___

1. Specific Objective and How Presented to Students: Students will demonstrate their understanding of the principle which determines the rate at which radioactive atoms decay.

2. Value to Students in Achieving the Objective: The students will have greater insight and understanding when assessing the issues of the nuclear age.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will introduce the concept of radioactive half-life. He/she will explain that the radioactivity of an element or isotope is measured by determining the specific period of time during which half of the radioactive atoms will decay. The teacher may use the chalkboard, overhead transparencies, filmstrips, etc., to help explain this concept. He/she should instruct the students in how to tabulate their data and how to record the data in graph form.

4. Guided Group Practice: The students may work in groups 2, 3, or 4. They are to follow the procedure described in the laboratory exercise, construct a data table, construct a graph, and answer the follow-up questions.

5. Independent Practice or Activity: The students will use the school library to find a copy or graph of a real radioactive decay curve of an element. They will compare what they discover in this laboratory exercise with what they find in the library. Class members will write a brief paper explaining the similarities and differences. Students may alternatively perform a laboratory investigation using a radioactive isotope with a short half-life and a Geiger counter to collect data which will be plotted on a graph and used to determine the half-life of the isotope.

6. Individual Differences and Learning Modalities:

   a. Remediation or Alternative Activities: The teacher will reread and outline the section in their test on nuclear chemistry. They will repeat the laboratory investigation under the close supervision of the teacher or with the assistance of a successful peer.

b. Enrichment or Supplemental Activities: The students may perform the experiment using a radioactive isotope and a Geiger counter or they may write a library research paper on natural radioactivity or the beneficial uses of radioactivity. They may want to research the sources and effects of natural radioactivity in our environment or the uses and effects of radioactivity on medical diagnosis, treatment of disease, chemical research, food preservation, and industrial applications such as quality control. Reports should be two pages long.

7. Evaluation: The student will participate in a discussion with the teacher about their experimental results. The graphs which they have drawn will be compared with all other graphs. The students' independent practice papers and their laboratory reports will be marked by the teacher.

LABORATORY EXERCISE SIMULATING RADIOATIVE DECAY OF AN ELEMENT

Materials:

50 one-inch cardboard squares, each marked on one side
Large shoe box with cover
Graph paper

Procedure:

1. Students will place the squares in a closed box and shake for about 30 seconds using a tumbling motion to assure that the squares will turn over.
2. Students then open the box and remove all squares with the marked side up. These represent atoms which have decayed.
3. Students count the numbers of squares remaining and record the total on the data table.
4. Students repeat this procedure until all the squares have been removed.
5. Students prepare a graph containing data. They mark the number of each trial along the bottom of the graph paper. They also mark the number of remaining squares along the left side of the graph paper. They use the two numbers--trial number and squares remaining after each trial--to locate each point on the graph. Finally, they draw a smooth curve through these points. (See the following pages for sample data table and graph showing some items to be completed by students.)

Follow-up Questions:

See the following pages for questions.

ADDITIONAL SUGGESTIONS FOR THE TEACHER:

Generally licensed quantities (10 uc) of isotopes with short half lives such as ^{131}I and ^{32}P are available through the Science Materials Center. Although most senior high schools should have a G-M counter, they are also available on loan from the Center.

Name ____________________

RATE OF RADIOACTIVE DECAY DATA SHEET*

Title: Investigating the Rate of Radioactive Decay

Purpose: To study the rate at which radioactive atoms decay.

Data:

(Data will vary.)

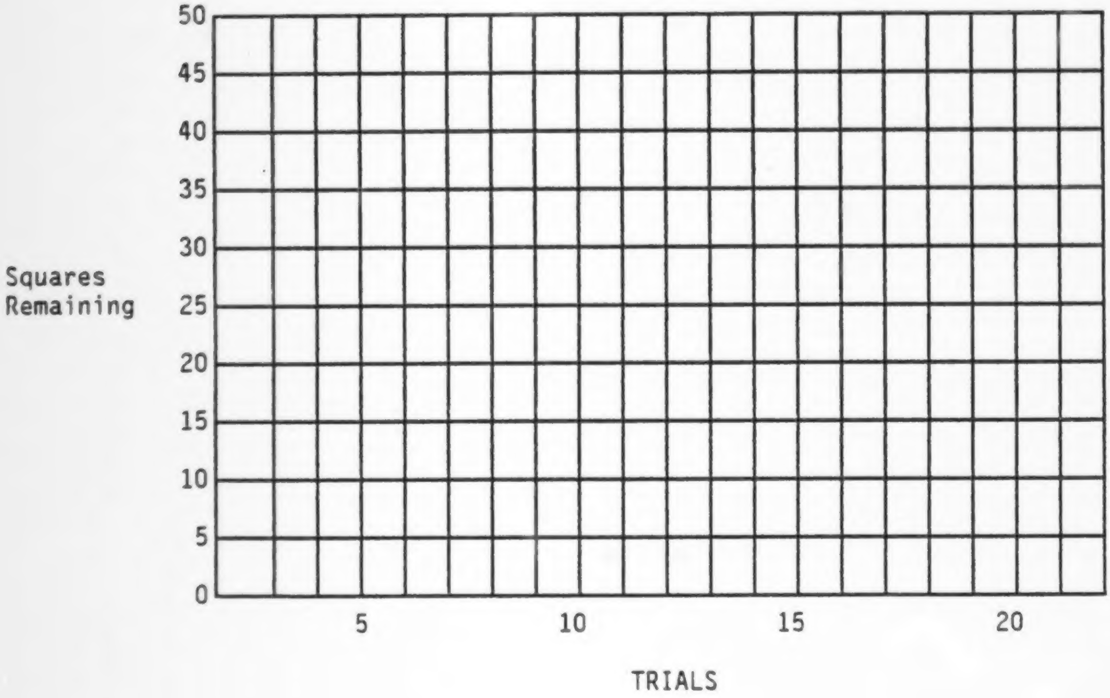
TRIAL	SQUARES REMAINING	TRIAL	SQUARES REMAINING
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

*Use the graph provided on the next page to plot the above results.

Questions:

1. How many trials were needed to remove all the squares? (Varies)
2. At which trial were most of the squares removed? (Should occur during earlier trials.)
3. At which trial were the fewest squares removed? (Should occur during later trials.)
4. What percentage of squares were removed on the first trial? ________
   What percentage would you have expected? (Should expect 50%.)

GRAPH OF RESULTS



SECTION IV:

APPENDICES

APPENDIX A - RESOURCES

Administrative Directives and Curricular Information. Los Angeles Unified School District: Office of Instruction, Publication No. SC-863.1, Stock No. 461260.

Audiovisual Materials Resource List, Secondary Schools Edition. Latest Revision. Los Angeles Unified School District: Audiovisual Services Section.

Blueprint for Bulletin Boards. Los Angeles Unified School District: Office of Secondary Instruction, Publication No. SC-824, 1983.

Catalog of Standard Supplies and Equipment for Elementary, Secondary, and Adult Schools. Latest Revision. Los Angeles Unified School District: Purchasing Branch.

Catalog of Films for Secondary and Adult Levels. Latest Revision. Los Angeles Unified School District: Audiovisual Services Section.

A Collection of Selected Goals and Objectives. Los Angeles Unified School District: Office of Instruction.

Conservation of Energy, Suggested Activities for Pupils. Los Angeles Unified School District: Instructional Planning Division, Publication No. EC-448. Available from Regional Science Center.

Evaluation Summary - Science Continuum Assessment, Version 1, 1980; Version 2, 1981. Los Angeles Unified School District: Office of Instruction.

Guidelines for Assignment of Homework for Elementary and Secondary Schools. Los Angeles Unified School District: Office of Instruction, Publication No. GC-67, 1978.

Guidelines for Instruction: Science, Secondary School Curriculum. Los Angeles Unified School District: Office of Instruction, Publication No. SC-769.19, 1984.

List of Authorized Textbooks, Junior and Senior High Schools and Community Adult Schools. Latest Revision. Los Angeles Unified School District: Textbook Services Section, Publication No. 426.

Marking Practices and Procedures for Elementary and Secondary Schools. An Instructional Bulletin. Los Angeles Unified School District: Office of Instruction, Publication No. GC-74, 1978.

Metrics (SI) for the Secondary Classroom. Los Angeles Unified School District: Office of Instruction, Publication No. SC-731, 1976. 186 pp.

Parents and Schools: A Shared Responsibility. Los Angeles Unified School District: Office of Instruction, Publication No. GC-96, 1983.

Precautions With Chemicals. Los Angeles Unified School District: Office of Instruction, Publication No. SC-865, 1984.

Putting Critical Thinking to Work. Los Angeles Unified School District: Office of Instruction, Publication No. EC-501, Stock No. 463180.

Reaching Higher Levels of Thought. Los Angeles Unified School District: Office of Instruction, Publication No. X-118, Stock No. 463320.

Safety and Workers Compensation Reference Guide. Los Angeles Unified School District, Sections 2370-45 through 2370-54, 1980.

Science Materials Center Catalog and Loan Equipment List for Senior High Schools, Order Forms and Other Information. Annually Revised. Los Angeles Unified School District: Office of Instruction.

Science Safety Handbook for California High Schools. California State Department of Education, 1987.

A Statement of Goals. Los Angeles Unified School District: Office of Instruction, Publication No. GC-31, 1975.

Study Center Activity Cards. Los Angeles Unified School District: Office of Instruction, Publication No. GC-32, Stock No. 463640.

Suggested Terminal Objectives: Science, Junior and Senior High Schools. Examples of Instructional Objectives, Together With Samples of Pre- and Post-Test Items. Los Angeles Unified School District: Office of Instruction, Publication No. SC-711.

Teaching the Essential Skills. Los Angeles Unified School District: Office of Instruction, Publication No. GC-82, Stock No. 463818.

Test-Taking Procedures and Techniques for Secondary School. Los Angeles Unified School District: Office of Instruction, Publication No. X-116, Stock No. 463897.

The Teaching of Values. Los Angeles Unified School District: Office of Instruction, Publication No. GC-56, Stock No. 463810.

Use Metric! Activities to Help Parents Get the "Feel" of SI Metric Units of Measure. A Teacher's Guide. Revised. Los Angeles Unified School District: Publication No. SC-726, 1979.

We Tried It. We Like It. Successful classroom practices. Los Angeles Unified School District: Office of Instruction, Publication No. GC-77, Stock No. 464415.

APPENDIX B

MODEL CURRICULUM STANDARDS, GRADES NINE THROUGH TWELVE: PHYSICAL SCIENCE. CALIFORNIA STATE DEPARTMENT OF EDUCATION, 1985

The following is a list of the standards for Physical Science which pertain to chemistry from the Model Curriculum Standards, Grades Nine through Twelve: Physical Science. California State Department of Education, 1985.

Individuals are referred to the entire document as it contains additional information including suggested activities which exemplify each standard.

1. Students understand the structure of atoms and molecules, including the component parts (e.g., electrons, neutrons, protons) and the bonds between atoms that give rise to molecules. In addition, the student will understand the differences between compounds and mixtures as commonly found in their environment. (MCS PS-1)

2. Students can identify examples of elements and compounds that form common items in their environment by means of their chemical and physical properties. In addition, students will appreciate the myriad of compounds that can be formed from different chemical combinations of elements. (MCS PS-2)

3. Students understand the three basic phases of matter and earth and the role temperature and pressure play in the change of phase. Students will be able to relate the kinetic theory model to matter around them. (MCS PS-3)

4. Students understand the elements are arranged in a periodic table. In addition, they learn that properties of elements are related to the number and "arrangement" of the electrons, protons, and neutrons that compose their atoms. (MCS PS-4)

5. Students learn to define, measure, and/or calculate various physical characteristics of substances (e.g., mass, weight, length, area, volume, and temperature. (MCS PS-5)

6. Students understand that chemical reactions can be classified according to the kind of rearrangement of atoms (synthesis, decomposition, replacement); the type of substances reacting (acid-base, oxidation-reduction); and whether energy is absorbed or released. Related considerations are the concepts of chemical equilibrium and the effects of temperature, pressure, and catalysts on reaction rates. (MCS PS-6)

7. Students understand the importance of the synthesis of new compounds which have properties needed to serve certain purposes. (MCS PS-7)

8. Students understand the basic concepts of nuclear science, including elementary particles, fission, fusion, plasma, radioactivity, half-life, and nuclear chain reactions. (MCS PS-8)

9. Students understand that energy has been described as the ability to do work and that energy appears in many forms that can neither be created nor destroyed but only exchanged among various bodies or converted from one form to another in a quantitative and reproducible way. (MCS PS-10)

10. Students understand the nature of waves (electromagnetic [including light], sound, fluid), sources, propagations, and interactions. (MCS PS-13)

11. Students describe the characteristics of the electromagnetic spectrum (with reference to the nature of the surfaces/materials they are incident upon.) (MCS PS-14)

12. Students understand heat, heat transfer, specific heat, and the differences between heat and temperature and their implications for calculating heat loss in isolated systems, converting heat into work. (MCS PS-15)

13. Students understand and appreciate the nature and role of electricity and electronics in the natural and the technological world. (MCS PS-16)